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(VCN 24-1C)

SKYLAB PROGRAM
CSM VERIFICATION ANALYSIS REPORT

Part Name EPS Radiator

Part Number V37-458010 & V37-310010

Date September 1970

Prepared by:

J. L. Schaefer
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15 Sept. 1970
Date

Approved by:

R. Johnson Mgr.
System Engineering Title

17 Sept 1970
Date

L. Bailis Supv
Design Assurance Title

9/18/70
Date

[Signature] Proj Engr
Project Engineering Title

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Date



Space Division
North American Rockwell

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TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

THIS DOCUMENT DESCRIBES THE APPLICATION OF THE SINDA COMPUTER PROGRAM FOR THE TRANSIENT THERMODYNAMIC SIMULATION OF THE APOLLO FUEL CELL/RADIATOR SYSTEM FOR THE LIMIT CONDITION OF THE PROPOSED SKYLAB MISSION. RESULTS ARE INCLUDED FOR THE THERMAL CONSTRAINTS IMPOSED UPON THE PRATT AND WHITNEY FUEL CELL POWER CAPABILITY BY THE BLOCK II EPS RADIATOR SYSTEM OPERATING UNDER THE SKYLAB FIXED ATTITUDE ORBITS.



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FOREWORD

The thermal analysis of Skylab fuel cell and radiator system capability, in support of Contract SA500, NAS9-150, was conducted between October 1969 and June 1970. Results of this work are contained in this report, which was prepared by J. L. Schaefer and G. A. Vanderpol of CSM Operations Analysis, Mission Requirements and Evaluation group. The original models of the electrical power system (EPS) radiator and Block I fuel cell, and the CINDA computer program were furnished by H. Cazemier and W. Simon of NASA-MSC. Early checkout runs were limited to leased Univac 1108 service and IBM 7094 emulation, which were slow and expensive. With the assistance of P. Jepsen of Aero and Thermal Projects, Scientific Programming, the IBM 360/SINDA program was obtained and converted to Space Division's IBM 360 formats. E. R. Arnold provided considerable assistance in developing the Block II fuel cell model for the SINDA program.

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1. INTRODUCTION

1.1 PURPOSE OF ANALYSIS

The range of output power capability for the Apollo fuel cell system is established by the requirement to operate within the command module (CM) bus voltage range of 26.5 to 31 volts and by the thermal constraints imposed by the fuel cell stack, condenser, and radiator temperature limits. This report considers only the thermal constraints in establishing the fuel cell power capability for Skylab missions. Under high transient-power levels, CM voltage requirements may be more limiting.

Early in 1969, NASA-MSC personnel furnished for the Skylab study the computer program, the Chrysler Improved Numerical Differencing Analyzer for Third Generation computers (CINDA-3G) (Reference 1), and heat transfer models of the Block II electrical power system (EPS) and the Allis-Chalmers fuel cell system. Subsequently at NR several major changes were made to these models and the CINDA program. The preliminary Allis-Chalmers model became obsolete after the decision was made to use the Pratt and Whitney (PW) Block II fuel cell for the Skylab mission. Therefore, a completely new PW fuel cell model had to be developed for CINDA. Several modifications were made to the EPS radiator model to provide closer correlation with qualification test data (Reference 2) and to include heat transfer between the radiator panels and the service module (SM) structure. Finally, the original CINDA-3G program, which was developed for use on the Univac 1108, was replaced with an advanced program version, Systems Improved Numerical Differencing Analyzer for Third Generator Computers (SINDA-3G), which had been converted (Reference 3) for operation on the IBM 360/75 computer.

1.2 VERIFICATION ANALYSIS REQUIREMENTS

Verification analysis requirements consist of a computer simulation. The simulation determines the effect of the thermal constraints on power capability with one fuel cell and with two fuel cells and with full and five-eighths EPS radiator area operation under the two extremes for Skylab fixed orbit environmental conditions. The SINDA-3G computer program is required for the eight cases of computer simulation. Results for each of the eight cases must be within the acceptable fuel cell temperature limits stated for the flight measurements.

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2. CONCLUSIONS

Analysis results indicate the EPS radiator subsystem has sufficient capability to reject the waste heat associated with the fuel cell power levels required for Skylab missions while maintaining the fuel cells within nominal temperature levels. The computer simulation considered sun-vector orbit plane angles (β) of 0.0 and 73.5 degrees for one and two fuel cells operating with full and five-eighths radiator areas. The maximum and minimum power levels evaluated in this study are listed in Table 1. Results are discussed in Section 4.4 of this report.

Table 1. Summary of Results for Fuel Cell/Radiator Power Capability for an Earth Orbit of 235 Nautical Miles

Fuel Cells (number operating)	Radiator Area (operating panels)	Minimum Total Current (amperes)	Maximum Total Current (amperes)
2	8	50	100
2	5	40	90
1	8	30	60
1	5	25	50

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3. RECOMMENDATIONS

Based upon results of this analysis, qualification and development test results, and Block II flight data, Block II fuel cell and EPS radiator subsystem capabilities are sufficient to meet Skylab mission requirements. No further testing or analysis is recommended.

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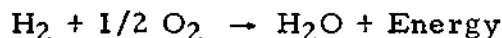
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4. ANALYSIS

4.1 ANALYTICAL MODELS

General Fuel Cell Model Considerations

The Pratt and Whitney fuel cell combines oxygen and hydrogen to produce electricity, heat, and water. The overall chemical reaction can be written as



The quantity of reactants required to produce a given amount of energy can be determined from Faraday's Laws of Electrolysis. As stated in Reference 4, these are:

1. The mass of a substance liberated in an electrolysis cell is proportional to the quantity of electricity passing through the cell.
2. When the same quantity of electricity is passed through different cells, the masses of the substances liberated are proportional to their electrochemical equivalents.

The combined laws can be used to express the amount of water produced per unit time in terms of current flow:

$$\dot{W}_{\text{H}_2\text{O}} = I * M / (F * n) \quad (1)$$

where

I = current (amperes)

M = molecular weight

F = Faraday's constant—96500 amp-sec/gm equivalent

n = gm equivalent/gm mole

W = weight flow per unit of time

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The following values of specific fuel consumption have been determined from the above equation:

0.0230 lb H₂O per amp-hr
0.0204 lb O₂ per amp-hr
0.00257 lb H₂ per amp-hr

Figure 1 depicts the basic schematic of the fuel cell thermodynamic components. Two coolant loops are used to remove the excess heat and water. The stack contains the 31 individual fuel cell elements, each of which consists of two electrodes and the KOH electrolyte, where the chemical reaction of hydrogen and oxygen occurs. Electrically the cells are connected in series. Each is capable of approximately 1 volt, depending on electrolyte condition and load. The temperature of the stack is maintained in the range of 390 to 460 F by means of the primary regenerator and bypass valve. The condenser and water separator are responsible for the water removal and the resulting water concentration in the electrolyte. The temperature range at which water is nominally condensed is 155 to 165 F.

This temperature range is controlled by the secondary regenerator bypass valve and the secondary regenerator. After some of the waste heat is used to heat the incoming reactants in the oxygen and hydrogen preheaters, the EPS radiators reject the excess heat to space. The analytical modeling for each major component is discussed in more detail in the next sections.

Voltage Output

The fuel cell terminal voltage is a function of load current, stack temperature, and electrolyte (KOH) water concentration. Reference 5 provides nominal fuel cell performance curves that depict voltage as a function of current and parametric values of stack (surface) temperature. These curves were expressed in the general polynomial form

$$V_t = A_1 + A_2 I + A_3 I^2 + A_4 I^3 + A_5 TS + A_6 (TS) (I) \\ + A_7 (TS) (I^2) + A_8 TS^2 + A_9 (I) (TS^2) + A_{10} TS^3 \quad (2)$$

where

V_t is voltage based on current and stack temperature (volts)

A_1, \dots, A_{10} are coefficients

I = load current (amperes)

TS = stack temperature (°F)

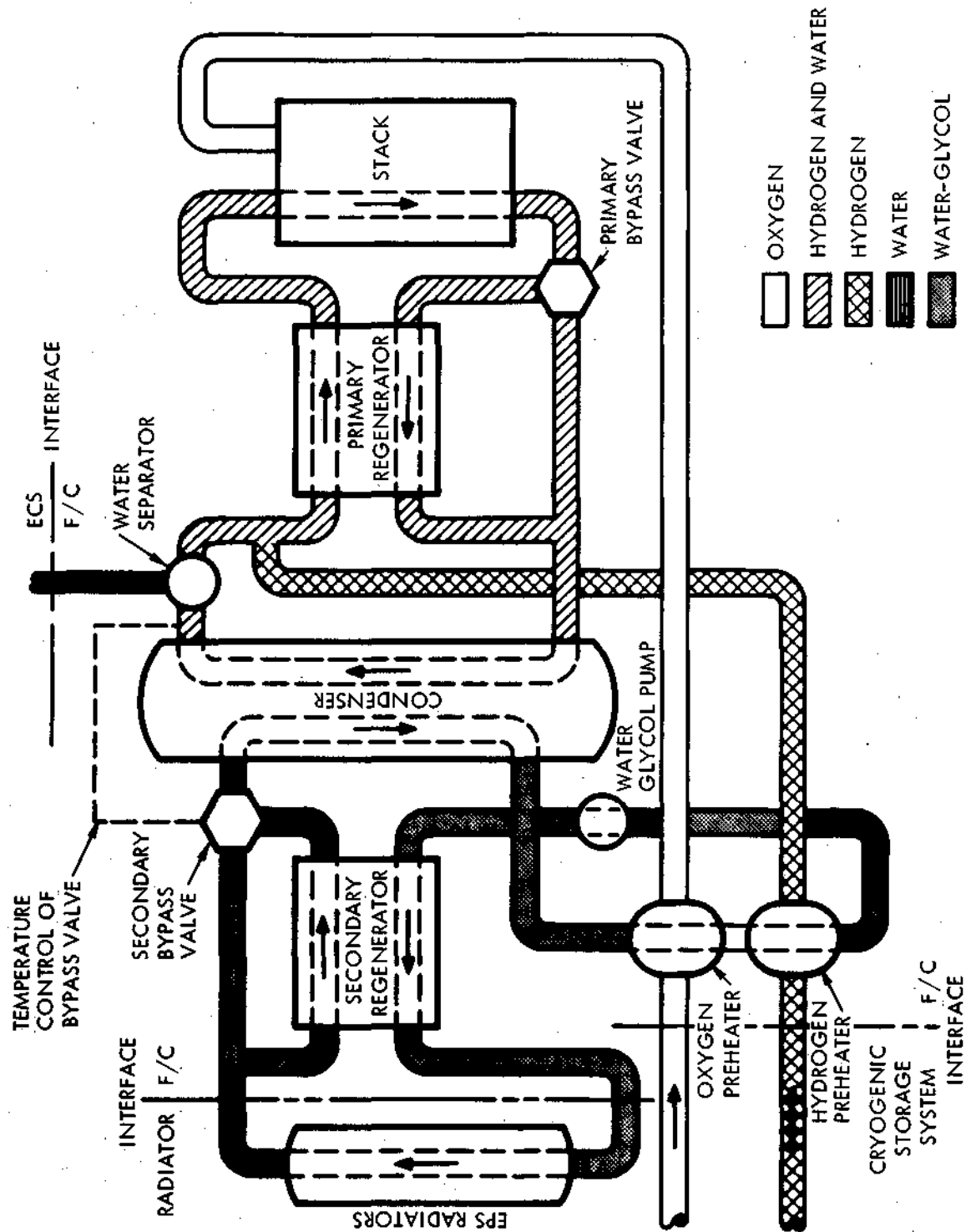


Figure 1. Fuel Cell Fluid and Component Schematic

A standard least squares surface fit bivariate polynomial routine was used in calculating the coefficients of this equation. The input data for the bivariate routine, as shown in Table 2, are the Reference 5 data corrected to a common KOH-water concentration of 0.75. The coefficients established from these data are given in Table 3. The resulting value, V_t , is corrected for the KOH-water concentration effect in the SINDA program by the following equation:

$$V = V_t - 0.241 (0.75 - PCKOH) \quad (3)$$

where

V = fuel cell voltage based on current, stack temperature, and KOH-water concentration (volts)

V_t = voltage based on current and stack temperature (volts)

$PCKOH$ = the weight ratio of KOH to KOH + water

The value of V is used in the program as the fuel cell terminal voltage.

Table 2. Input Data for Bivariate Routine

Current (amperes)	Stack Temperature (°F)				
	380	400	420	440	460
15.0	30.0	30.8	31.4	31.8	31.9
20.0	29.1	30.0	30.6	31.0	31.3
25.0	28.3	29.2	29.9	30.4	30.7
30.0	27.5	28.5	29.4	29.8	30.1
35.0	26.7	27.8	28.8	29.2	29.6
40.0	26.0	27.2	28.2	28.7	29.0
45.0	25.3	26.5	27.6	28.2	28.5
50.0	24.6	25.9	27.0	27.7	28.1

Table 3. Output Coefficients From Bivariate Routine

A_1	5.583364	A_6	4.686233×10^{-3}
A_2	-1.308438	A_7	-3.573639×10^{-7}
A_3	2.054927×10^{-3}	A_8	-1.525995×10^{-5}
A_4	-1.333418×10^{-5}	A_9	-4.889387×10^{-6}
A_5	9.694690×10^{-2}	A_{10}	-1.292755×10^{-7}

Primary Loop Thermodynamics

Excess heat and steam produced in the chemical reaction in the stack are removed by the recirculating stream of hydrogen and water. The energy balance computation for the stack is based upon the total energy of reaction as input to the stack and the electrical power, stack temperature change, recirculating fluid temperature change, and fuel cell heat loss as output energy. The reaction energy is determined by

$$Q_{GENAT} = 51600. * SFCH2 \quad (4)$$

where

Q_{GENAT} = reaction energy (Btu/hr)

$SFCH2$ = hydrogen consumption rate (lb/hr)

51600 Btu/lb is the lower heating value of hydrogen

The heat balance on the stack is given by

$$Q_{STORD} = Q_{GENAT} - Q_{H2} - Q_{O2} - Q_{ELECT} - Q_{RS} - Q_{SM} \quad (5)$$

where

Q_{STORD} = heat gained in the stack (Btu/hr)

Q_{GENAT} = reaction energy (Btu/hr)

Q_{H2} = heat gained by the consumed hydrogen (Btu/hr)

Q_{O2} = heat gained by the consumed oxygen (Btu/hr)

QSELECT = electrical energy output (Btu/hr)

QRS = heat gained by the recirculating hydrogen-water stream
(Btu/hr)

QSM = heat lost by the stack to the SM structure (Btu/hr)

A similar equation can be expressed for the primary loop heat balance:

$$QCOND = QGENAT - QSELECT - QSM - QH2O \quad (6)$$

where

QCOND = heat transferred across the condenser (Btu/hr)

QH2O = energy in the condensed water above the 70 F datum
(Btu/hr)

QGENAT, QSELECT, and QSM are as previously defined.

After the two equations are balanced, the temperature can be determined in the primary loop by the following three equations:

$$TSE = TSTACK + (QSTORD * DTIMEU / 30.) \quad (7)$$

where

TSE = the new stack temperature (°F)

TSTACK = the previous stack temperature (°F)

QSTORD = the stack heat gain (Btu/hr)

DTIMEU = the time step (hr)

30. = the stack mass-specific heat product (Btu/°F)

$$TSI = TSE - QSR / (WDTCPI + WDTCPI2) \quad (8)$$

where

TSI = recirculating stream temperature at stack inlet (°F)

TSE = recirculating stream temperature at stack outlet (°F)
(as well as the stack temperature)



QSR = heat gained by the recirculating hydrogen-water stream
(Btu/hr)

WDTCP1 = the mass-specific heat product of the water in the
recirculating stream

WDTCP2 = the mass-specific heat product of the hydrogen in the
recirculating stream

$$TCIP = TCEP - (QCOND - CONST2)/(WDTCP1 + WDTCP2) \quad (9)$$

where

TCIP = recirculating stream temperature at condenser primary
inlet (°F)

TCEP = recirculating stream temperature at condenser primary
outlet (°F)

CONST2 = heat of vaporization of the condensed water

QCOND, WDTCP1, WDTCP2 are as previously defined.

The TCEP is determined in the condenser subroutine, which is
described in the next section.

The mass balance in the primary loop is determined by assuming a
constant volume delivery of 3 cfm at 60 psia for the primary pump for cal-
culating the specific volume of the hydrogen and water at the stack inlet and
outlet and at the condenser inlet and outlet. The partial pressure of water
is first determined at the condenser exit, based upon the condenser exit
temperature and a saturated steam condition. At the stack, the recirculating
steam enters at this same condition and leaves at the temperature and the
partial pressure of water in the electrolyte. Figure 2 illustrates the relation-
ship of the electrolyte temperature, partial pressure of water, and KOH
concentration. The program computes the equilibrium water pressure at
the condition of electrolyte temperature and concentration at the beginning
of the time step. This pressure is assumed to equal the partial pressure of
water in the hydrogen-water stream at the stack exit at the end of the time
step. Thus, the water balance is determined from the following equations:

$$WH202P = I*0.0230 * DTIMEU \quad (10)$$

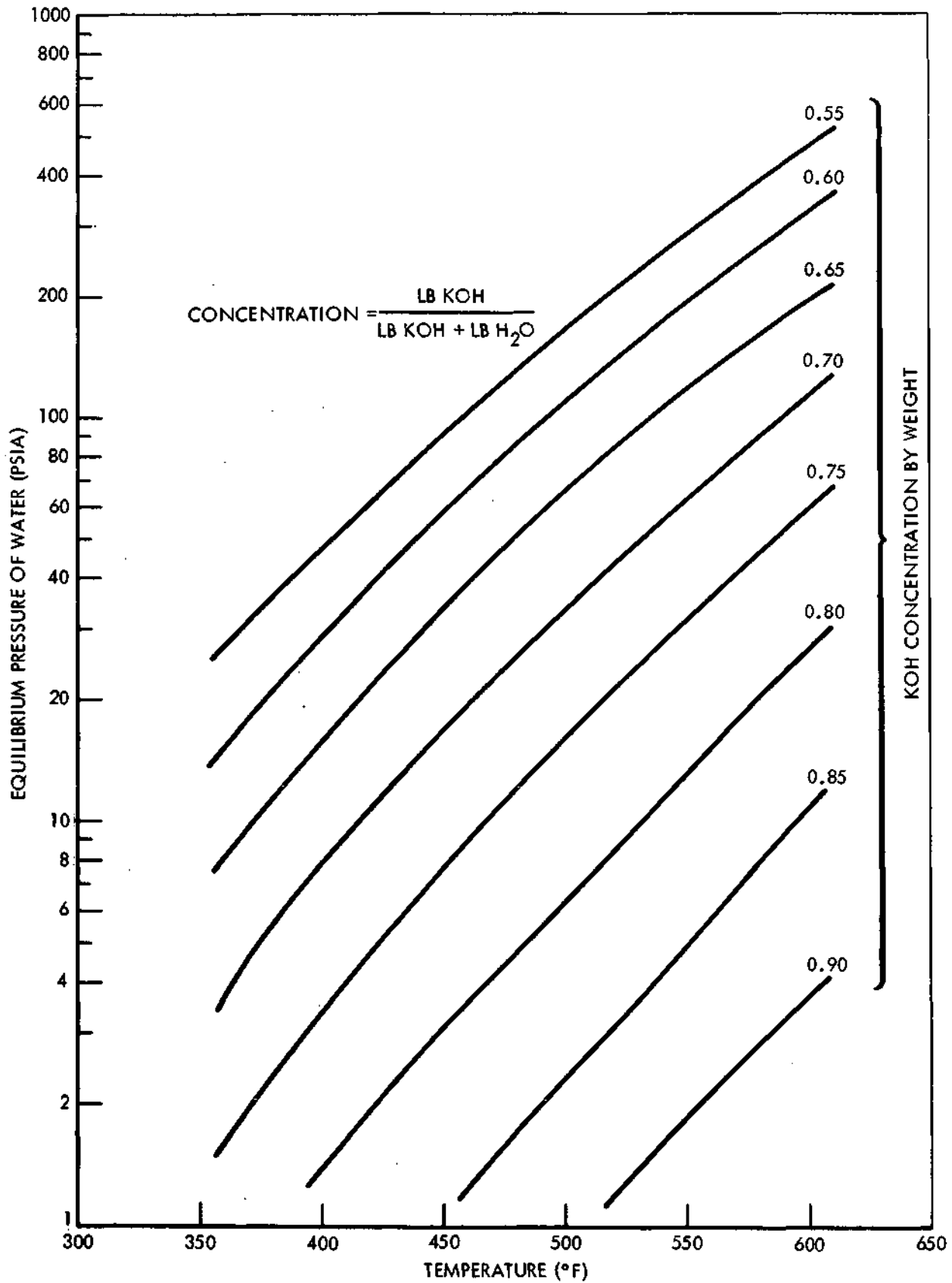


Figure 2. Water Pressure of KOH Electrolyte

where

WH202P = weight of water produced within the time step (lb)

I = current (amps)

DTIMEU = time step (hours)

0.0230 is the conversion factor for pounds of water produced per ampere-hour

$$WH2025 = WH2026 + WH202P * RATE \quad (11)$$

where

WH2025 = weight of water in the electrolyte at the end of the time step (lb)

WH2026 = weight of water in the electrolyte at the start of the time step (lb)

RATE = the percent of water produced during the time step that remains in the stack. RATE is calculated by an iterative balance between the water specific volume at the stack inlet and at the stack outlet and the water production rate.

$$PCKOH = 22.0 / (22.0 + WH2025) \quad (12)$$

where

PCKOH = electrolyte concentration (ratio of KOH weight to total electrolyte weight)

KOH weight is 22.0 pounds

WH2025 is as previously defined

The mass balance of water at the condenser uses the specific volume of water determined at the stack outlet as the specific volume of water at the condenser inlet. The specific volume of water at the condenser outlet is determined by the condenser primary exit temperature, TCEP, and a saturated steam condition.

The amount of water condensed is found as follows:

$$DMASS = (180./SVOL11)*DTIMEU - (180./SVOL21)*DTIMEU \quad (13)$$

where

DMASS = water condensed (lb)

SVOL11 = specific volume of water at the condenser outlet
(cu ft/lb)

SVOL12 = specific volume of water at the condenser inlet
(cu ft/lb)

DTIMEU = time step (hours)

The mass balance for the reactants is based on providing the necessary flow to support the theoretical consumption rates without consideration of minor variations in regulated pressure:

$$SFCH2 = 8.292 * 10^{-5} * 31. * I \quad (14)$$

$$SFCO2 = 7.94 * SFCH2 \quad (15)$$

where

SFCH2 = hydrogen specific fuel consumption (lb/hr)

SFCO2 = oxygen specific fuel consumption (lb/hr)

The energy balance involving the consumed reactants is discussed in the Reactant Preheater section.

Condenser

The condenser is a counterflow heat exchanger interfacing the primary and secondary loops of the fuel cells. The condenser transfers the heat of the hydrogen-water mixture of the primary loop to the water-ethylene glycol mixture of the secondary loop. The normal operating range of the condenser exit temperature on the primary side (TCEP), which controls the secondary regenerator bypass valve, is 155 to 165 F.

Several schemes were considered for defining condenser performance. The method used, in view of simplicity of interface between the primary and secondary loops, was the balance of heat flow across the condenser. Data describing the condenser were obtained from Reference 6 and are provided in Figure 3 in the form of condenser performance curves. A multiple linear

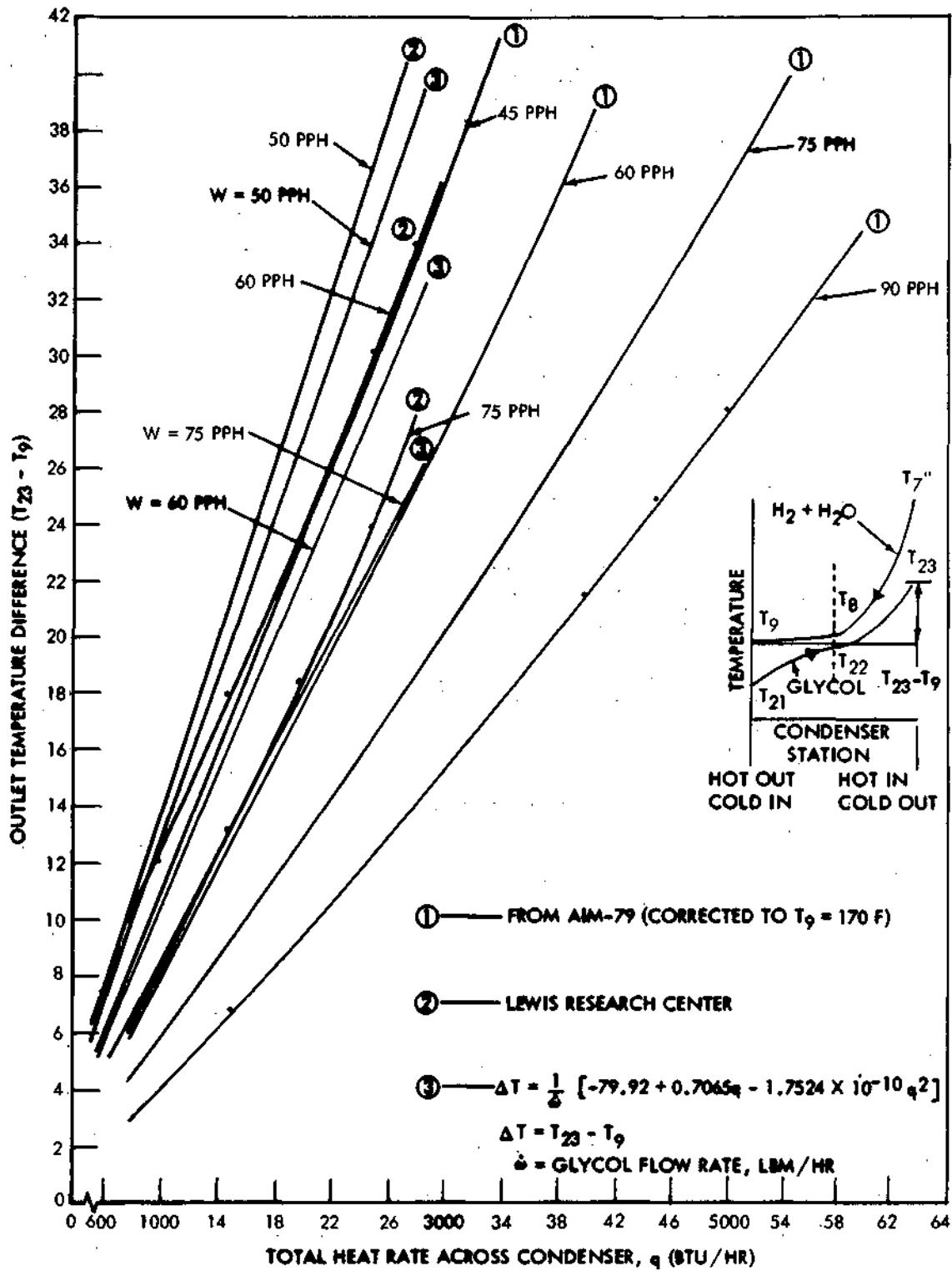


Figure 3. Condenser Performance Curves

regression scheme was then used to curve-fit the data. The following equation was obtained:

$$\text{TCEP}-\text{TCES} = (1./\text{WDWG}) * (49.229 + 0.68747 * \text{QCOND} + 9.0145\text{E}-7 * \text{QCOND} ** 2) \quad (16)$$

where

TCEP = condenser primary side exhaust temperature (°F)

TCES = condenser secondary side exhaust temperature (°F)

WDWG = water-glycol flow rate (lb/hr)

QCOND = heat flow across the condenser (Btu/hr)

The program makes successive approximations to balance the heat flow across the condenser. A value of QCOND is calculated from the primary loop parameters. Then the condenser glycol and gas exit temperatures are varied in accordance with Equation (16) until the heat lost to the glycol equals the QCOND calculated from the primary loop.

Secondary Regenerator and Bypass Valve Models

The secondary regenerator is modeled as a two-port network. The empirical relationships used for this model are typical for a counterflow heat exchanger and were taken from Reference 7. The hot outlet temperature, t_{h2} , can be written as

$$t_{h2} = (C_c / C_h) \epsilon (t_{c1} - t_{h1}) + t_{h1} \quad (17)$$

where

$$C_c = W_c C_p(T)$$

$$C_h = W_h C_p(T)$$

W_c, W_h = coolant flow rates on cold and hot sides (lb/hr)

$C_p(T)$ = coolant specific heat (a function of temperature)

ϵ = regenerator effectiveness

t_{c1} = cold side inlet temperature (°F)

t_{h1} = hot side inlet temperature (°F)

Figure 4 is a diagram of the regenerator with assigned terms.

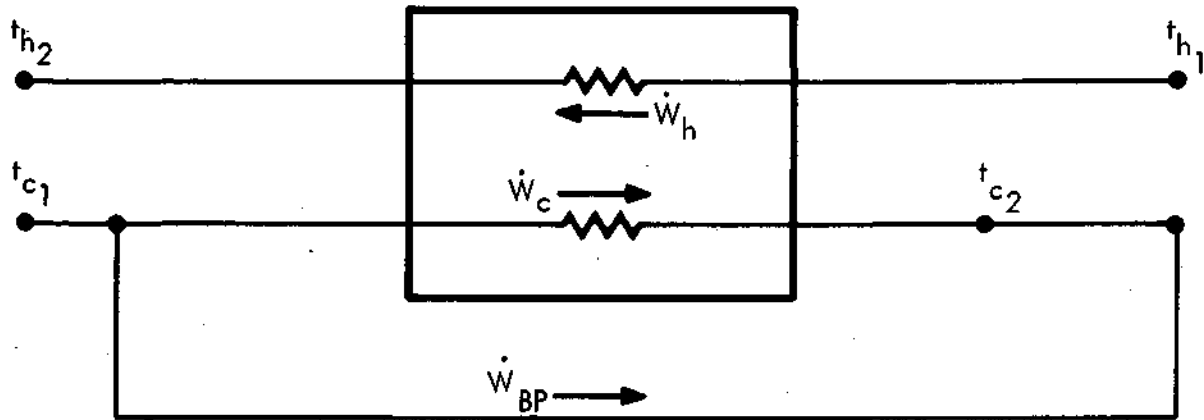


Figure 4. Secondary Regenerator Diagram

From Equation (17), the capacity ratio, C_c/C_h , can be rewritten as

$$C_c/C_h = \frac{\dot{W}_c \left(\frac{1}{t_{c2} - t_{c1}} \right) \int_{t_{c1}}^{t_{c2}} C_p dT}{\dot{W}_h \left(\frac{1}{t_{h1} - t_{h2}} \right) \int_{t_{h2}}^{t_{h1}} C_p dT} = \frac{\dot{W}_c \Delta T_h \Delta h_c}{\dot{W}_h \Delta T_c \Delta h_h} \quad (18)$$

where

t_{c2} = cold-side outlet temperature ($^{\circ}\text{F}$)

ΔT = change in temperature ($^{\circ}\text{F}$)

Δh = change in enthalpy (Btu/lb)

Since the flow on the cold side of the regenerator is regulated by the secondary bypass valve, which is controlled by the primary condenser exit temperature, the portion of the cold-side flow that is bypassed must be considered. The relationship of the bypass flow rate, \dot{W}_{BP} , and the bypassed fraction, $\alpha = \dot{W}_{BP}/\dot{W}_h$, and the cold- and hot-side flow rates are given by the following equations:

$$\dot{W}_h = \dot{W}_c + \dot{W}_{BP} \quad (19)$$

$$\dot{W}_c/\dot{W}_h = 1 - \alpha \quad (20)$$



Equation (18) can then be rewritten by using the above expressions to give

$$C_c/C_h = (1 - \alpha) \frac{\Delta T_h \Delta h_c}{\Delta T_c \Delta h_h} = \beta \quad (21)$$

The parameters ϵ and β , together with the factor τ_{ij} , to represent the time response, define the relationship between the inlet and outlet temperatures of the regenerator:

$$\begin{bmatrix} t_{c2} \\ t_{h2} \end{bmatrix} = \begin{bmatrix} (1 - \epsilon)\tau_{11} & \epsilon\tau_{12} \\ \epsilon\beta\tau_{21} & (1 - \epsilon\beta)\tau_{22} \end{bmatrix} \begin{bmatrix} t_{c1} \\ t_{h1} \end{bmatrix} \quad (22)$$

This relation is solved in the program by a group of subroutines that update sliding arrays, move backward in the arrays to simulate delay, and perform integration. Figure 5 illustrates the relationship of the secondary regenerator cold-side inlet temperature to the regenerator effectiveness for various coolant flow rates. The data above an inlet of 70 degrees have been extrapolated.

The secondary bypass valve characteristics are shown in Figure 6. The program keeps track of the TCE in ascending or descending order and correspondingly interpolates on the correct curve.

Radiator System

The fuel cell and radiator system consists of eight 5-square-foot panels located on the CSM fairing. For the Skylab mission only two of the fuel cell and radiator coolant loops will be filled and connected for two-fuel-cell operation. While the radiator model discussion in this section is for the basic three-fuel-cell operational mode, two-fuel-cell operation for Skylab is simulated by using a zero flow pump characteristic for the third cell. For one-fuel-cell contingency operation, zero flow pump characteristics are used for two of the three cells. Reduced radiator area operation for low-power operation for Skylab missions is the same as for other Apollo missions: The bypass valve is actuated, and the last three panels are bypassed, and five-panel (five-eighths) radiator operation is achieved.

The original radiator model was included with the data deck for the CINDA program received from NASA (Reference 8). The model included a nodal network for each of the eight radiator panels and the coolant delivery and bypass lines. Figure 7 illustrates the nodal model that is typical for a single radiator panel. The solid and fluid node and conductor numbers shown in this figure represent panel 1 in the radiator system model. The corresponding node capacitance and conductor valves are given in Table 4. The

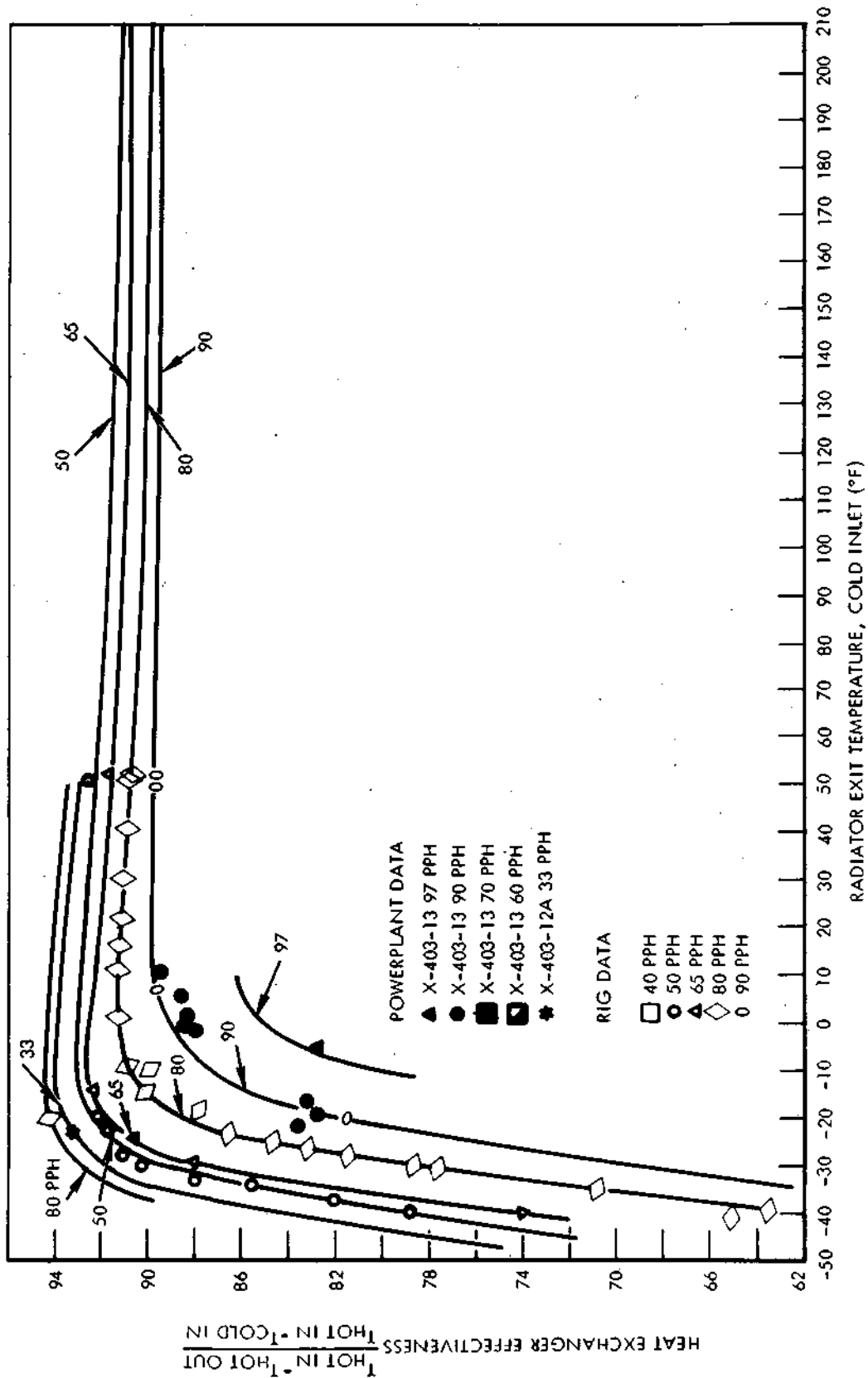


Figure 5. Secondary Regenerator Effectiveness

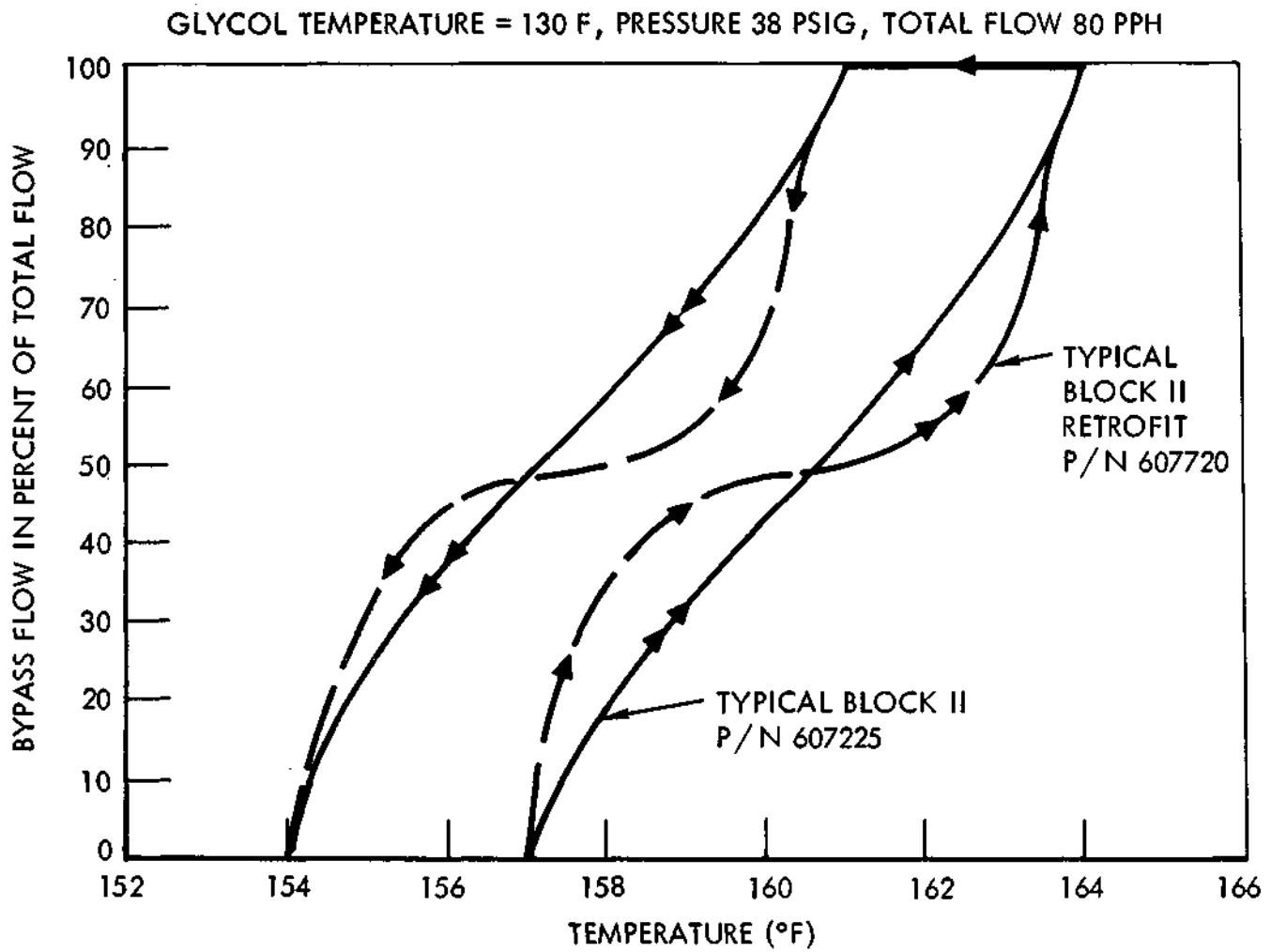


Figure 6. Secondary Bypass Valve Characteristics

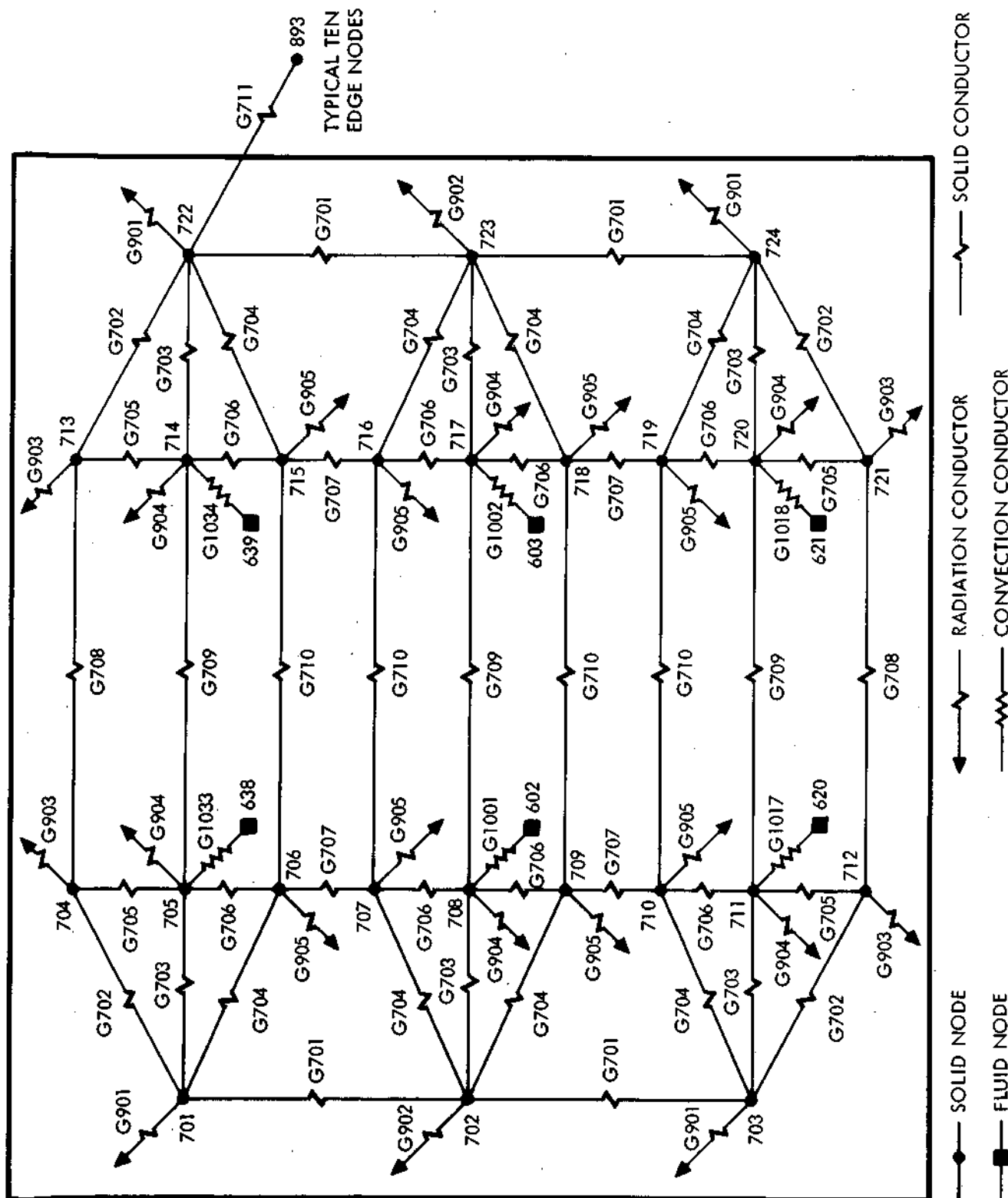


Figure 7. Typical Radiator Panel Nodal Network

Table 4. Capacitance and Conductance Values

Solid Node Number	Solid Node Capacitance $\rho C_p V$ (Btu/°F)	Solid Conductor Number	Conductor Value KA/L (Btu/Hr °F)
701	0.043269	701	0.199691
702	0.037088	702	0.176766
703	0.043269	703	0.090127
704	0.098515	704	0.121294
705	0.080002	705	3.111299
706	0.067608	706	3.927239
707	0.067608	707	3.422037
708	0.080002	708	0.106059
709	0.067608	709	0.182910
710	0.067608	710	0.072776
711	0.080002	711	0.010989
712	0.098515	Radiation Conductor Number	Conductor Value $\sigma \epsilon FA$ (Btu/hr °F ⁴)
713	0.098515		
714	0.080002	901 902 903 904 905	0.2298 x 10 ⁻⁹ 0.1970 x 10 ⁻⁹ 0.5234 x 10 ⁻⁹ 0.2700 x 10 ⁻⁹ 0.3591 x 10 ⁻⁹
715	0.067608		
716	0.067608		
717	0.080002		
718	0.067608		
719	0.067608		
720	0.080002		
721	0.098515		
722	0.043269		
723	0.037088		
724	0.043269		
893	0.000000		

original values for the solid conductors were increased ten percent after it was found that the foil was two to three times thicker than required by the original specifications (Reference 9). Loss of heat through the radiator panel edges to the SM structure was accounted for by adding another solid node to the nodal network to represent the SM structure. Each of the solid-edge nodes of the eight radiator panels was tied to this SM structure node by a solid conductor. A structure temperature within a ± 150 F range and an infinite capacitance is assigned the structure node, depending upon the environment being simulated.



The fuel cell/radiator coolant is a water-ethylene glycol solution composed of 62.5 percent ethylene glycol by weight. The coolant properties used in the analysis as functions of temperature are density (Figure 8); conductivity (Figure 9); specific heat (Figure 10); viscosity (Figure 11); and relative enthalpy (Figure 12). The coolant pump characteristic, flow versus pressure drop in the radiator loop, is shown as Figure 13. The pressure drop in the radiator loop is calculated by using the Fanning equation with a dynamic head loss factor in the subroutine (Reference 8).

Reactant Preheaters

In the secondary loop, the water-glycol, after exiting from the condenser, flows through the reactant preheaters before passing into the secondary regenerator. The basic equations simulating the reactant preheaters were taken from Reference 10, with corrections made to preserve compatibility with the secondary loop model.

The effectivity of the oxygen preheater is shown in Figure 14 and expressed as

$$EFF = 0.53 + 0.002 * WDWG + 0.018 * WDO2 \quad (23)$$

where

EFF = effectivity

WDWG = water-glycol flow rate (lb/hr)

WDO2 = oxygen flow rate (lb/hr)

The oxygen preheater outlet temperature can then be found from Equations (23) and (24):

$$TO2O = TO2I + (TWGOI - TO2I) * EFF \quad (24)$$

where

TO2O = oxygen outlet temperature (°R)

TO2I = oxygen inlet temperature assumed constant = 530°R

TWGOI = water-glycol temperature at condenser outlet (°R)

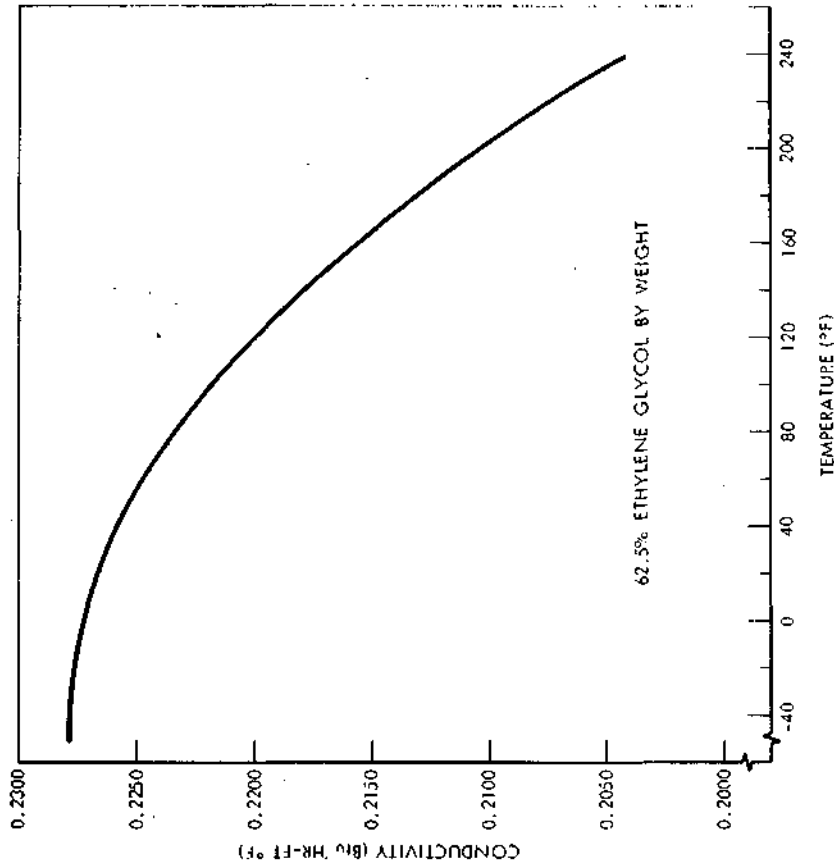


Figure 9. Conductivity of Water-Glycol Mixture

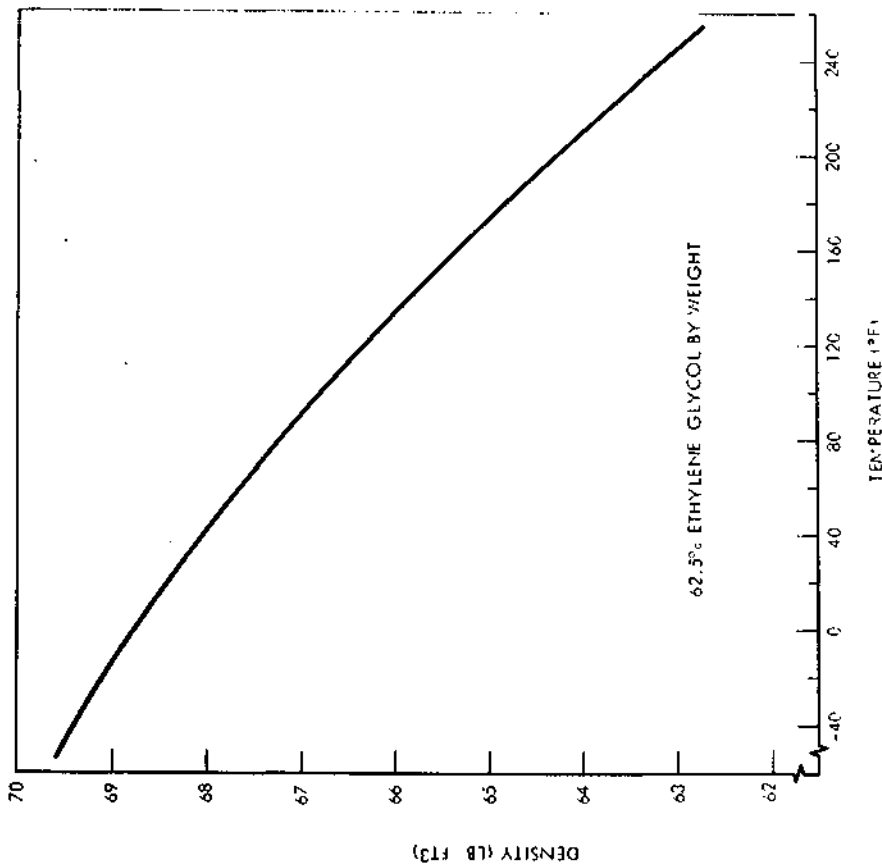


Figure 8. Density of Water-Glycol Mixture

C

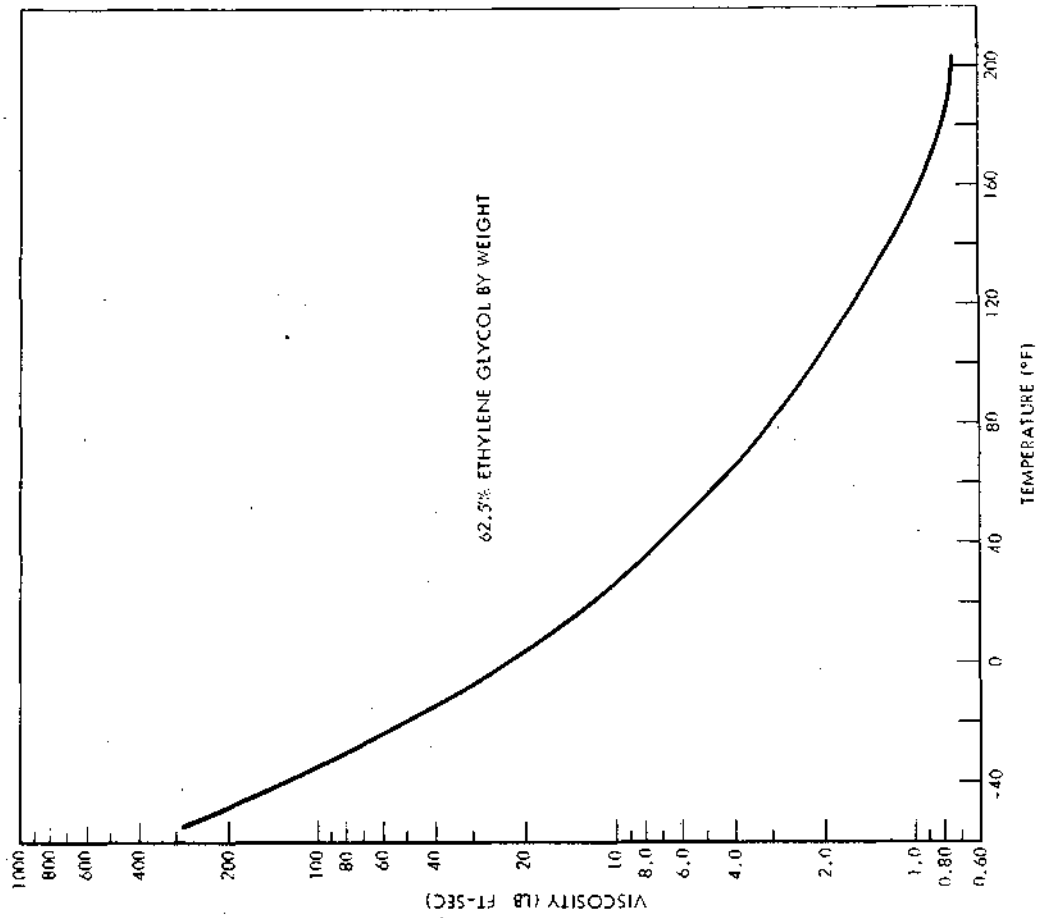


Figure 11. Viscosity of Water-Glycol Mixture

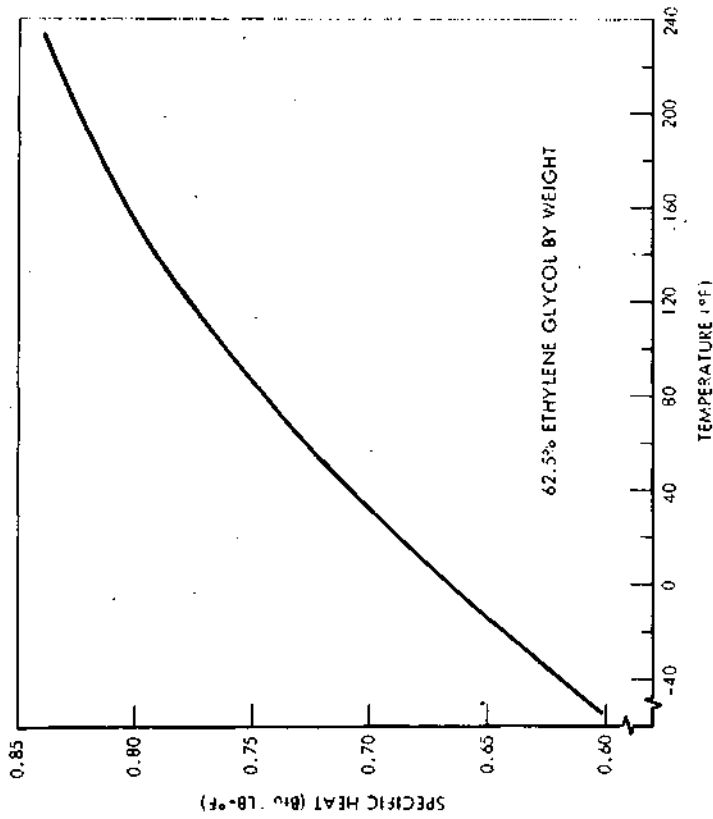


Figure 10. Specific Heat of Water-Glycol Mixture

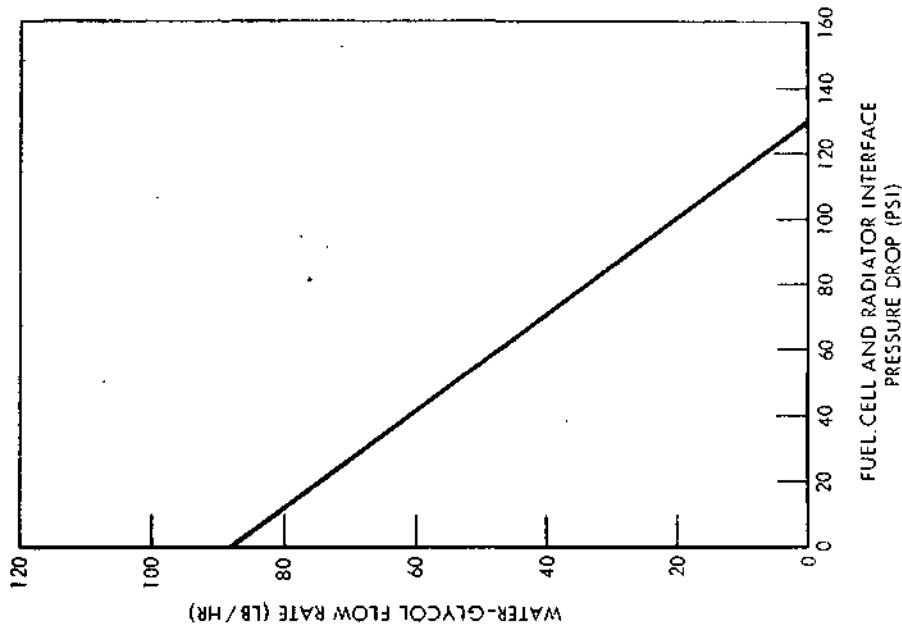


Figure 13. Water-Glycol Pump Characteristic

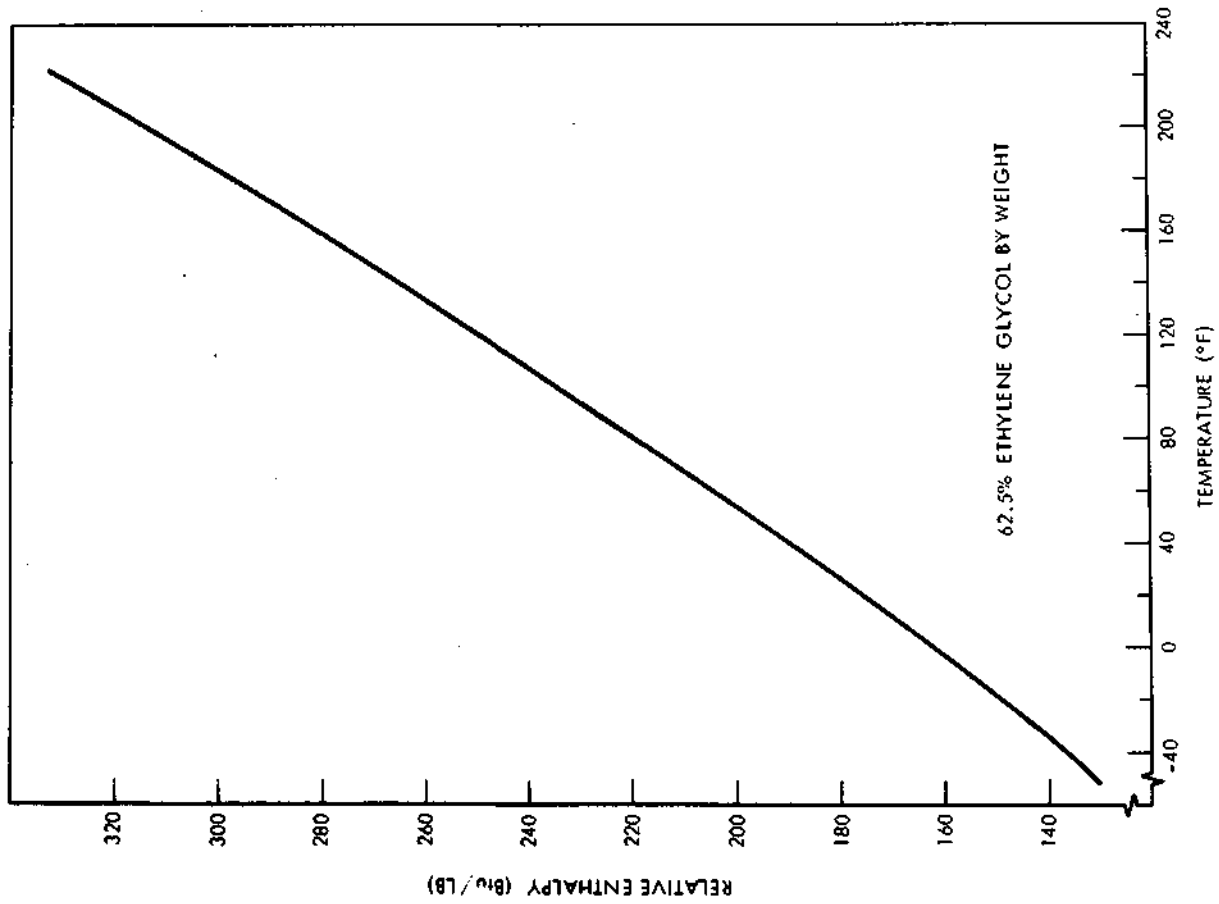
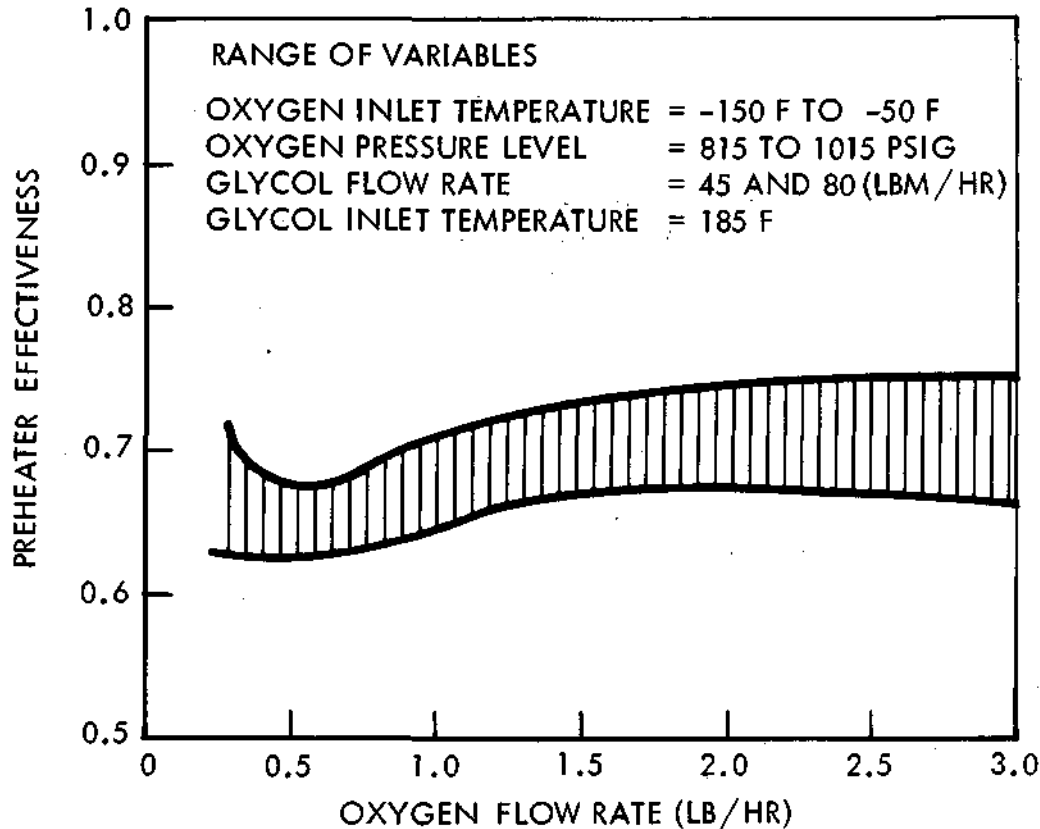


Figure 12. Relative Enthalpy of Water-Glycol Mixture



(FROM P&WA MONTHLY PROGRESS REPORT, PWA - 2345, 25 MAY 1964)

Figure 14. Oxygen Preheater Effectiveness

From Equation (25), the change in enthalpy of the water-glycol flowing through the oxygen preheater can be obtained:

$$DHO2 = (TO2I - TO2O) * (0.152 + 0.0000225 * (TO2O + TO2I)) * WDO2 / WDWG \quad (25)$$

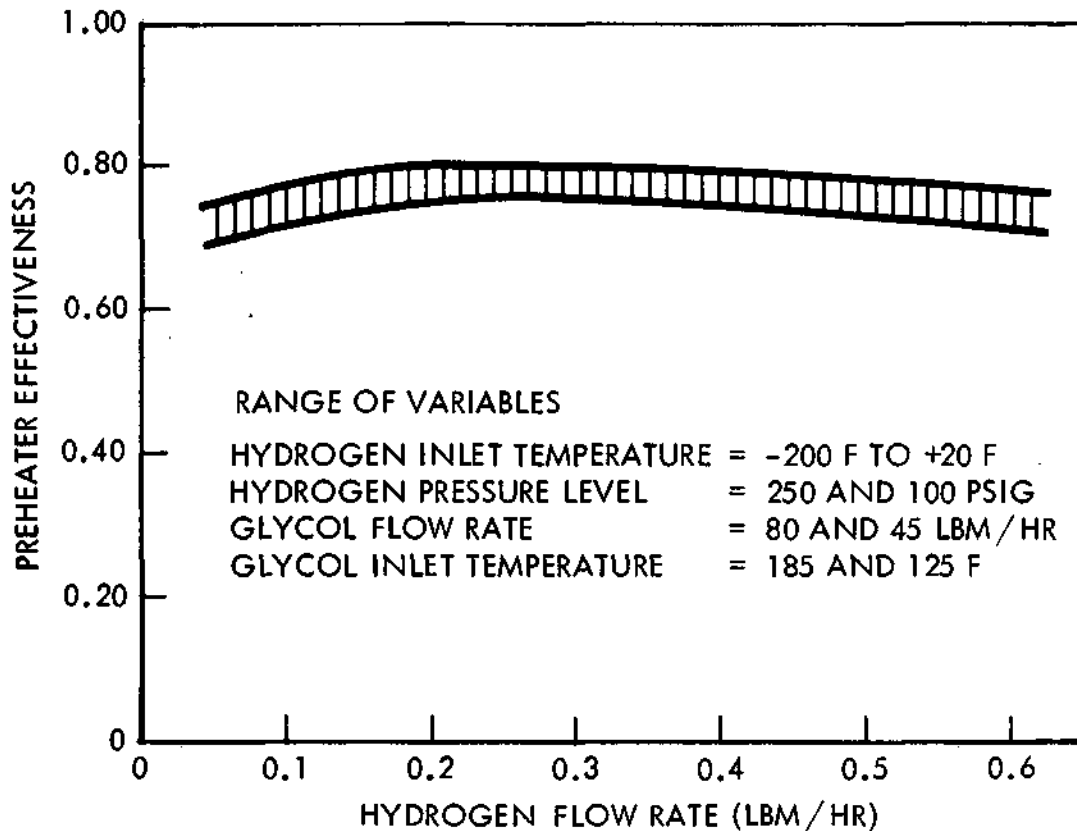
where

DHO2 = enthalpy change of the water-glycol through the oxygen preheater (Btu/lb)

The temperature of the water-glycol (TWGHI) exiting the oxygen preheater is found from the change in enthalpy and preheater water-glycol inlet temperature.

The effectivity of the hydrogen preheater is assumed constant at 0.75 (Figure 15). Equation (26) is similar to Equation (24) and gives the hydrogen preheater outlet temperature:

$$TH2O = TH2I + 0.75 * (TWGHI - TH2I) \quad (26)$$



(FROM P&WA MONTHLY PROGRESS REPORT, PWA - 2332, 27 APRIL 1964)

Figure 15. Hydrogen Preheater Effectiveness

where

TH2O = hydrogen outlet temperature ($^{\circ}$ R)

TH2I = hydrogen inlet temperature, assumed constant = 530° R

TWGH1 = water-glycol temperature at hydrogen preheater inlet ($^{\circ}$ R)

The enthalpy change of the water-glycol flowing through the hydrogen preheater is then

$$DHH2 = (TH2I - TH2O) * 3.47 * WDH2 / WDWG \quad (27)$$

where

WDH2 = hydrogen flow rate (lb/hr)

DHH2 = enthalpy change in the water-glycol through the hydrogen preheater (Btu/lb)

The temperature of the water-glycol exiting the hydrogen preheater can then be found from the enthalpy change and the water-glycol temperature

entering the preheater. The water-glycol exit temperature is taken as the inlet temperature of the hot side of the secondary regenerator.

Fuel Cell Heat Loss to Structure

The fuel cell heat loss to the SM structure is based upon information given in Reference 5. The data as shown in Reference 5 are plots of fuel cell heat loss as a function of stack temperature for three parametric structure temperatures: 30, 80 and 130 F. These data were replaced with the following linear equation, which is used in the SINDA fuel cell model:

$$QSM = 3.25 * TS - 1.6 * TA - 882. \quad (28)$$

where

QSM = fuel cell heat loss to structure (Btu/hr per cell)

TS = fuel cell stack temperature (°F)

TA = ambient structure temperature (°F)

The ambient temperature is assigned as an independent parameter, based upon space environmental conditions. A temperature of 30 F is selected for extreme cold conditions; 130 F for extreme hot conditions, and 80 F for nominal conditions. There is no attempt to determine the direct heat conduction through the fuel cell cone mount nor to determine the heat radiation from the pressure jacket and accessory package components. The program does not attempt to determine the changes in the ambient structure temperature resulting from such heating. The equation is accurate to within ± 4 percent of the data from Reference 5.

4.2 PROGRAM DEFINITION

The CINDA-3G (Chrysler Improved Numerical Differencing Analyzer for Third-Generation Computers) computer program was developed by the Thermodynamics Section of the Aerospace Physics Branch of the Chrysler Corporation Space Division at the National Aeronautics and Space Administration's Michoud Assembly Facility. The CINDA-3G program, written to run on the Univac 1108, was converted by the Computer Science Branch of the Idaho Nuclear Corporation to run on the IBM 360/75 computer. The converted program, called SINDA-3G (Systems instead of Chrysler), provides a variety of methods for the solution of thermal analog models presented in a network format. The network representation is unique in that it has a one-to-one correspondence to both the physical model and the mathematical model. The program allows the models to be developed through use of combinations of FORTRAN statements, user-initiated subroutines, and the numerous subroutines contained within the program. These program subroutines can be used for handling interrelated complex phenomena such as



sublimation; diffuse radiation within enclosures; simultaneous, one-dimensional, incompressible, fluid flow, including valving and transport delay effects; and similar areas associated with heat transfer and fluid flow.

In the hands of a competent engineering analyst, the SINDA-3G program is a powerful tool for analyzing thermal systems.

4.3 MODEL AND PROGRAM INPUT

Data Deck Setup

A SINDA-3G program deck contains two main blocks: a data block and an operations block. Each block is subdivided into four blocks. The four data blocks are entitled the NODE DATA, CONDUCTOR DATA, CONSTANTS DATA, and ARRAY DATA. The four operations blocks are designated EXECUTION, VARIABLES 1, VARIABLES 2, and OUTPUT CALLS.

Card columns 12 through 80 comprise the data field. The instruction field (operations blocks) consists of columns 12 through 72. The program processes the problem data into FORTRAN common data and converts instructions into FORTRAN source language. They are then passed on to the system FORTRAN compiler. Instruction cards containing an F in column 1 are passed on exactly as received. Discussion of the operations blocks will follow discussion of the data blocks.

Data input to the data blocks may be one or more integers, floating numbers (with or without the E exponent designation), or alphanumeric words of up to six characters each. The reading of a word or number continues until a comma is encountered. Then the next word or number is read. Words or numbers may not be broken between cards, and a new card is equivalent to starting with a comma. Therefore, no continuation designation is required. When sequential commas are encountered, the program places floating-point zero values between them. Reading continues until the terminal column is reached or a dollar sign is encountered. Comments for a data card can be placed after a dollar sign and are not processed by the program.

The first card in each of the four data blocks must be started in column 8 with the mnemonic code BCD (binary coded decimal), then an integer (1 through 9) in column 12, and the name of the data block starting in column 13. Each data block must be terminated with a mnemonic END card.



The NODE DATA block contains the data describing all nodes in the network. Each set of node data is grouped similar to the following code:

column 12
N#, Ti, Ca

where

N# = integer node number
Ti = initial node temperature
Ca = node capacitance

All nodes are numbered by the program sequentially (from 1 on) in the order received. The user input number is designated the actual node number. The program assigned number is termed the relative node number.

Second in the group of data blocks is the CONDUCTOR DATA block. In the nodal network, nodes are joined together with conductors. The three types of conductors used in the SINDA-3G program are conduction (solid), convection, and radiation conductors. Conductors are input to the program with the code.

column 12
G#, NA, NB, Cn

where

G# = integer conductor number
NA = one adjoining node number
NB = the other adjoining node number
Cn = conductance value

If more than one conductor has the same constant value, they may share the same conductor number and value. This is accomplished by placing two or more pairs of integer-adjoining node numbers between the conductor number and value.

The data for the CONSTANTS DATA block are always input as doublets, the constant name or number followed by its value. They are divided into two types, control constants and user constants, and may be intermingled within the block. User constants receive a number. Control constants have alphanumeric names.



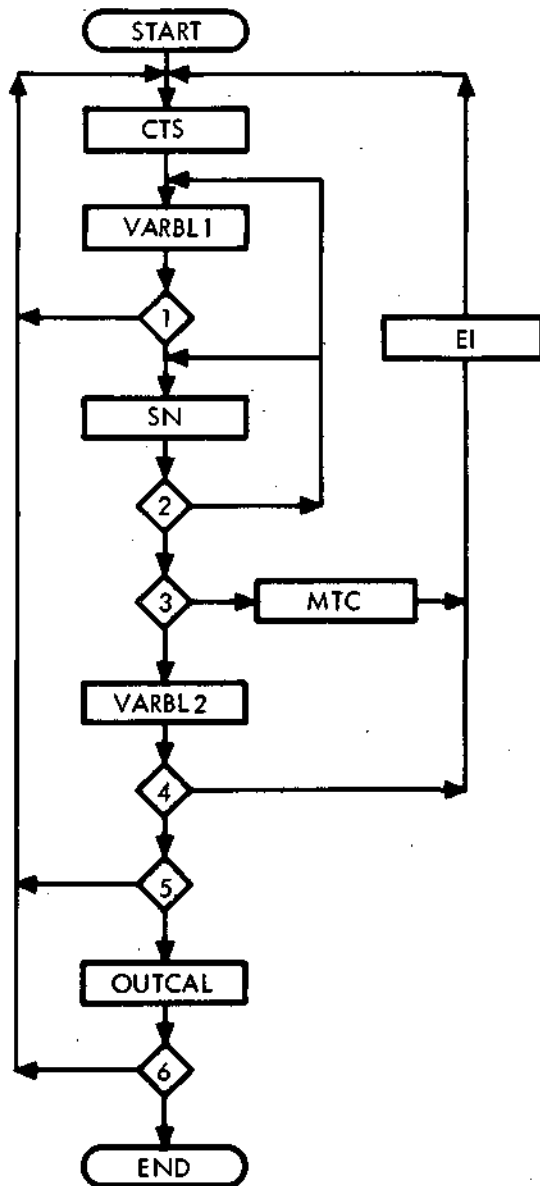
The ARRAY DATA block is the last of the four data blocks. Input of data into this block is exceedingly simple. The array number is listed, followed by the sequential listing of the data, and terminated with an END (data END, not mnemonic). The interpolation and matrix subroutines of the program make extensive use of these arrays. The SPACE option in the ARRAY DATA block is an easy way for the user to specify a large number of locations, which are initialized by the preprocessor program as floating-point zeros. When this option is used, the array number is listed, followed by the word SPACE and the number of locations to be initialized, and terminated with an END.

While the four data blocks provide the data for the program, the four operations blocks determine the program control. This they do through the use of various operations and instructions. The four operations blocks, EXECUTION, VARIABLES 1, VARIABLES 2, and OUTPUT CALLS, are preprocessed by the SINDA-3G program and passed on to the system FORTRAN compiler as four separate subroutines entitled EXECTN, VARBL1, VARBL2, and OUTCAL, respectively. Figure 16 illustrates the basic flow diagram for the solution of the network.

When the FORTRAN compilation is successfully completed, control is passed to the EXECTN subroutine. It sequentially performs the operations in the same order as input by the user in the EXECUTION block. None of the operations specified in the other three blocks is performed unless it is called for either directly by name in the EXECUTION block or internally by some other called for subroutine. All operations and instructions listed in EXECUTION block and performed by the program are executed only once. Because of this feature, the EXECTN subroutine can be used to initialize constants and variables, fabricate new arrays, establish steady-state parameters, and perform other operations that are completed only once during the duration of the program.

The operations in the VARIABLES 1 block can be considered pre-solution operations. These operations may include construction of temperature arrays, establishment of heating rates, calculation of heating sources, or other basic operations required for solution of the thermal nodal network.

In the same respect, the VARIABLES 2 block operations may be thought of as post-solution operations. VARIABLES 2 allows the user to look at the recently solved network. Typical operations of the VARBL2 subroutine may include integration of flow rates, corrections of empirical relationships to reflect thermal solution of the nodal network, updating of conductances to account for changes in node temperatures, etc.



OPERATION	DESCRIPTION
CTS	CALCULATE TIME STEP
VARBL1	VARIABLES 1 OPERATIONS
SN	SOLVE NETWORK
VARBL2	VARIABLES 2 OPERATIONS
OUTCAL	OUTPUT CALLS OPERATIONS
MTC	MODIFY TIME CONTROL
EI	ERASE ITERATION
CHECK	REVERSE DIRECTION IF
1	BACKUP NONZERO
2	RELAXATION CRITERIA NOT MET
3	TIME OR TEMP CHANGE TOO LARGE
4	BACKUP NONZERO
5	NOT TIME TO PRINT
6	PROBLEM STOP TIME NOT REACHED

Figure 16. Basic Flow Chart for Network Solution Subroutines

The operations in the OUTPUT CALLS block are performed on the output interval specified by the user in the program. Since the operations are performed only at the output interval, OUTPUT CALLS typically contains only instructions for outputting information.

The aforementioned data and operations blocks constitute a SINDA-3G program data deck. The deck must be terminated with the following card:

```
column 8      12  
BCD  3END OF DATA
```

The user has the option to use the subroutines contained in the SINDA-3G library or to write his own. When non-SINDA-3G subroutines are being called, the data communication is obtained through subroutine arguments similar to any other subroutine.

Sample Problem Input Data

The listing of the sample input data is included in the appendix. The data are presented in the same order as stated in the Data Deck Setup section: the node data first, followed by the conductor data and constants data, and concluded with the array data.

The node data includes the solid temperature nodes for the eight radiator panels, the water-glycol fluid temperature nodes for the three-fuel-cell system, the fluid pressure nodes, and the edge sink and environmental sink nodes for the eight panels.

The 11 solid (conduction) conductors are the first of the data listed in the conductor data. Next are the convection conductors and the pressure and fluid flow conductors for the three systems. The conductor data are concluded with the five radiation conductors.

The constants data contain the 472 constants used in the program. These constants are listed by their actual number rather than the program-assigned relative numbers.

Listed in the last section of the problem input data are the array data. Eighty-four arrays are listed, with most arrays containing data and the remaining arrays using the SPACE option to allocate program storage locations.

Following the input data is a listing of the main program (EXECUTN, VARBL1, VARBL2, and OUTCAL) and the 12 user-written subroutines.

Sample Problem Output

Figure 17 illustrates a typical problem output listing. The listing is headed with the title "Systems Improved Numerical Differencing Analyzer * SINDA * North American Rockwell Corporation - Space Division" and followed by 11 output interval data sets. Each output interval data set is started with four asterisks. The first data line contains five control constants with their values listed to the right of each constant. The last three constants have the relative node number enclosed in parentheses. The control constants are:

TIME	Present mission time (hr)
DTIMEU	Last time step used for transient network problem (hr)
CSGMIN	Most recent minimum stability criteria for the network
DTMPCC	Maximum diffusion temperature change calculated over the last time step
ARLXCC	Maximum arithmetic relaxation change calculated over the last iteration

The next four lines of output are associated with the primary loop operation. The first two lines list the titles, with the values following. The titles are defined as follows:

SYSTEM	Fuel cell system in operation (for Skylab configuration only two fuel cell systems are used, systems 1 and 3)
POWER	Fuel cell power output (watts)
CURRENT	Fuel cell output current (amps)
VOLTAGE	Fuel cell output voltage (volts)
TSI	Stack inlet temperature (°F)
TSE	Stack exit temperature (°F)
TCIP	Condenser inlet temperature, primary loop (°F)
TCEP	Condenser exit temperature, primary loop (°F)
QCOND	Heat flow across the condenser (Btu/hr)



W-COND	Weight rate of water condensed (lb/hr)
WS-RATE	Percent of water produced in the time interval that remains in the stack (%)
TO2	Oxygen reactant temperature at stack inlet (°F)
TH2	Hydrogen reactant temperature before mixing with the primary recirculation stream (°F)
PCKOH	Electrolyte concentration ratio

Secondary loop operations are listed in the next four lines, with the titles followed by their values. The titles represent:

FLOW RATE	Water glycol flow rate (lb/hr)
QRAD	Heat flow across the radiators (Btu/hr)
TRADIN	Temperature of the radiator inlet (°F)
TRADOUT	Temperature of the radiator outlet (°F)
DPRAD	Pressure drop through the radiator loop (psi)
TSRCI	Temperature of the secondary regenerator at the cold-side inlet (°F)
TSRCE	Temperature of the secondary regenerator at the cold-side exit (°F)
TSRHI	Temperature of the secondary regenerator at the hot-side inlet (°F)
TSRHE	Temperature of the secondary regenerator at the hot-side exit (°F)
TCIS	Condenser inlet temperature, secondary loop (°F)
TCES	Condenser exit temperature, secondary loop (°F)
BPFS	Bypassed ratio at the secondary regenerator

The final data group lists the radiator inlet and outlet temperature for the eight radiator panels for all three systems. The temperatures are listed in degrees Fahrenheit. The four asterisks following this data group designate the start of a new output interval data set.

* * * *
TIME 5.49999E-01 DTIMEU 1.67292E-03 CSGMIN(8) 3.06978E-03 DTMPCC(152) 1.12518E-01 APLXCC(196) 1.40869E-01

SYSTEM	POWER WATTS	CURRENT AMPS	VOLTAGE VOLTS	TSI DEGF	TSE DEGF	TCIP DEGF	TCEP DEGF	QCOND BTU/HR	W-COND LB/HR	WS-RATE PERCENT	TO2 DEGF	TH2 DEGF	PCIOH
1	1303.97	45.00	28.98	357.50	437.05	234.16	135.62	2931.22	1.466	-41.60	133.78	137.48	0.735
3	1303.97	45.00	28.98	357.50	437.05	234.18	135.65	2930.12	1.465	-41.54	133.80	137.51	0.735

SYSTEM	FLOW RATE LB/HR	QRAD BTU/HR	TRADIN DEGF	TRADOUT DEGF	DPRAD PSI	TSRCI DEGF	TSRCF DEGF	TSRHI DEGF	TSRHE DEGF	TCIS DEGF	TCES DEGF	BPFS
1	84.66	824.69	84.20	71.08	5.055	71.22	116.23	159.77	84.11	116.23	160.06	0.0
3	84.62	819.52	84.57	71.53	5.128	71.66	116.26	159.81	84.47	116.26	160.10	0.0

PANEL 1		PANEL 2		PANEL 3		PANEL 4		PANEL 5		PANEL 6		PANEL 7		PANEL 8	
IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
83.8	83.4	82.8	82.2	80.4	78.7	77.0	75.4	73.7	73.0	72.2	71.6	71.0	71.0	71.1	71.1
69.4	69.0	55.4	54.5	47.0	44.4	28.5	26.8	38.3	57.5	56.3	50.1	49.5	67.4	67.3	67.3
84.2	84.0	83.0	82.2	80.4	78.7	77.5	76.3	73.9	73.1	72.4	71.9	71.5	71.5	71.5	71.5

* * * *
TIME 5.99999E-01 DTIMEU 1.66243E-03 CSGMIN(8) 3.07111E-03 DTMPCC(152) 9.87169E-02 APLXCC(196) 1.24390E-01

SYSTEM	POWER WATTS	CURRENT AMPS	VOLTAGE VOLTS	TSI DEGF	TSE DEGF	TCIP DEGF	TCEP DEGF	QCOND BTU/HR	W-COND LB/HR	WS-RATE PERCENT	TO2 DEGF	TH2 DEGF	
1	1305.09	45.00	29.00	357.19	437.49	234.69	135.40	2939.13	1.465	-41.59	133.70	137.43	0.735
3	1305.08	45.00	29.00	357.19	437.49	234.71	135.44	2937.78	1.465	-41.51	133.72	137.45	0.735

Figure 17. Sample Problem Output



4.4 ANALYTICAL RESULTS

Three temperature levels are monitored to determine if the fuel cells are operating within the specified limits. These temperatures are measured at the condenser primary exit, the radiator exit, and the stack. The nominal condenser primary exit temperature range is 155 to 165 F, with allowable cycling to 200 F. The caution and warning (C&W) alarms for the condenser exit are set for 150 F and 175 F. For the analysis, the acceptable minimum power operation was defined for condenser operation as between 150 and 155 F. The acceptable maximum power operation was defined as between 165 and 200 F. The stack and radiator exit temperatures are less limiting than the condenser exit temperature. This is evidenced by results in which seven of the eight cases reached the condenser exit limits. The remaining case was limited by the stack temperature.

The nominal stack temperature range is 390 to 460 F, with the C&W alarms at 360 F and 475 F. For the analysis, the acceptable minimum stack temperature range was 360 to 390 F. The maximum was defined as 460 to 475 F. The radiator exit-temperature nominal range is 0 to 120 F, with allowable high-temperature cycling to 180 F. The C&W alarm is set only for the minimum temperature condition of -30 F. Only the acceptable minimum radiator temperature range was defined for the analysis. This range, -30 to 0 F, was not encountered in any of the eight cases.

Two environmental heating profiles were used for the heat that is radiated to radiator panels. The hotter environment, which was used for the maximum power cases, has a β angle of 73.5 degrees for a circular earth orbit of 235 nautical miles with the vehicle in a Z-local vertical attitude hold. The colder environment for the minimum power cases uses a β angle of 0 degrees for the same orbit and attitude conditions.

The power levels shown in Tables 1, 5 and 6 represent the expected power requirements for the Skylab missions. One-fuel-cell operation and five-eighths radiator area are contingency operation modes that are considered irreversible. That is, once the contingency mode is selected, a return to normal two-fuel-cell or full-area operation is never required.

With the exception of Case 2, the power levels shown in Table 5 can be raised slightly by operation at the condenser C&W limit of 175 F. Operation to 200 F is acceptable for peak cycling conditions. However, once the nominal bypass limit of 165 F is exceeded, a slight increase in power results in a significant temperature rise. Case 3, one fuel cell, full area at 60 amperes, is the only case where the stack temperature limits the power. In this case, a greater increase in power is available if operated to the stack temperature C&W limit of 475 F.

For all of the minimum power cases listed in Table 6, slightly lower power capability is possible by operating down to the condenser C&W limit of 150 F. The temperatures shown in Tables 5 and 6 are orbital extremes except where differences occurred between fuel cells in two-fuel-cell operation. Then the value shown is the average between the two cells at the orbital extreme condition.

Table 5. System Temperatures for High Power Levels

Case	β Angle (deg)	Number of Fuel Cells in Operation	Radiator Area (operating panels)	Total Fuel Cell Current Level (amps)	System Temperatures (°F)			
					Condenser Exit	Stack	Radiator Inlet	Radiator Outlet
1	73.5	2	8	100.	168.45	455.93	189.87	150.58
2	73.5	2	5	90.	192.01	452.11	208.98	178.48
3	73.5	1	8	60.	163.77	470.24	190.24	138.04
4	73.5	1	5	50.	172.98	458.70	194.06	155.91

Table 6. System Temperatures for Low Power Levels

Case	β Angle (deg)	Number of Fuel Cells in Operation	Radiator Area (operating panels)	Total Fuel Cell Current Level (amps)	System Temperatures (°F)			
					Condenser Exit	Stack	Radiator Inlet	Radiator Outlet
5	0.	2	8	50.	154.30	418.25	52.85	33.03
6	0.	2	5	40.	151.46	412.36	66.11	49.82
7	0.	1	8	30.	155.06	426.05	47.12	19.08
8	0.	1	5	25.	153.41	419.54	46.71	24.57

5. REFERENCES

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2. EPS Radiator Thermal Vacuum Environment Qualification Test Block II. North American Rockwell Space Division, SID 66-1909 (1 March 1967).
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4. Thompson, R. A., and G. A. Swanson and R. H. Shaw. Fuel Cell System Thermodynamic Analysis. Pratt and Whitney Aircraft, Division of United Aircraft, East Hartford, Connecticut (18 December 1961).
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6. Weinstein, M. B. Apollo Fuel-Cell Condenser Heat Transfer Tests. NASA Lewis Research Center (123-34-02-01-22, 1966).
7. Giedt, Warren H. Principles of Engineering Heat Transfer. New York: D. Van Nostrand Company, Inc. (1957).
8. Personal communication from Harry J. Cazemier. "Development of a Thermal Analog Model of the Block II Electrical Power System Radiators for the Chrysler Improved Numerical Differencing Analyzer (CINDA) Computer Program," NASA Manned Spacecraft Center, Houston, Texas (February 1969).
9. "EPS CINDA Radiator Model," IL 695-202-110-69-099 by G. A. Vanderpol. North American Rockwell Space Division (23 October 1969).
10. Simulation of the Apollo Applications CSM Electrical Power System. North American Rockwell Space Division, SD 69-269 (December 1969).



APPENDIX: INPUT DATA, MAIN PROGRAM LISTING, AND USER SUBROUTINE LISTINGS

INPUT DATA

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```

BCD 3THERMAL SPCS
END
BCD 3NODE DATA
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 1)
  701,100...0432693,702,100...0370880,703,100...0432693
  704,100...0985149,705,100...0800018,706,100...0676083
  707,100...0676083,708,100...0800018,709,100...0676083
  710,100...0676083,711,100...0800018,712,100...0985149
  713,100...0985149,714,100...0800018,715,100...0676083
  716,100...0676083,717,100...0800018,718,100...0676083
  719,100...0676083,720,100...0800018,721,100...0985149
  722,100...0432693,723,100...0370880,724,100...0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 2)
  725,100...0432693,726,100...0370880,727,100...0432693
  728,100...0985149,729,100...0800018,730,100...0676083
  731,100...0676083,732,100...0800018,733,100...0676083
  734,100...0676083,735,100...0800018,736,100...0985149
  737,100...0985149,738,100...0800018,739,100...0676083
  740,100...0676083,741,100...0800018,742,100...0676083
  743,100...0676083,744,100...0800018,745,100...0985149
  746,100...0432693,747,100...0370880,748,100...0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 3)
  749,100...0432693,750,100...0370880,751,100...0432693
  752,100...0985149,753,100...0800018,754,100...0676083
  755,100...0676083,756,100...0800018,757,100...0676083
  758,100...0676083,759,100...0800018,760,100...0985149
  761,100...0985149,762,100...0800018,763,100...0676083
  764,100...0676083,765,100...0800018,766,100...0676083
  767,100...0676083,768,100...0800018,769,100...0985149
  770,100...0432693,771,100...0370880,772,100...0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 4)
  773,100...0432693,774,100...0370880,775,100...0432693
  776,100...0985149,777,100...0800018,778,100...0676083
  779,100...0676083,780,100...0800018,781,100...0676083
  782,100...0676083,783,100...0800018,784,100...0985149
  785,100...0985149,786,100...0800018,787,100...0676083
  788,100...0676083,789,100...0800018,790,100...0676083
  791,100...0676083,792,100...0800018,793,100...0985149
  794,100...0432693,795,100...0370880,796,100...0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 5)
  797,100...0432693,798,100...0370880,799,100...0432693
  800,100...0985149,801,100...0800018,802,100...0676083
  803,100...0676083,804,100...0800018,805,100...0676083
  806,100...0676083,807,100...0800018,808,100...0985149
  809,100...0985149,810,100...0800018,811,100...0676083
  812,100...0676083,813,100...0800018,814,100...0985149
  815,100...0676083,816,100...0800018,817,100...0985149
  818,100...0432693,819,100...0370880,820,100...0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 6)
  821,100...0432693,822,100...0370880,823,100...0432693
  824,100...0985149,825,100...0800018,826,100...0676083
  827,100...0676083,828,100...0800018,829,100...0676083
  830,100...0676083,831,100...0800018,832,100...0985149
  833,100...0985149,834,100...0800018,835,100...0676083
  836,100...0676083,837,100...0800018,838,100...0676083
  839,100...0676083,840,100...0800018,841,100...0985149
  842,100...0432693,843,100...0370880,844,100...0432693

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REM RADIATOR SOLID TEMPERATURE NODES (PANEL 7)
845,100.,.0432693,846,100.,.0370880,847,100.,.0432693
848,100.,.0985149,849,100.,.0800018,850,100.,.0676083
851,100.,.0676083,852,100.,.0800018,853,100.,.0676083
854,100.,.0676083,855,100.,.0800018,856,100.,.0985149
857,100.,.0985149,858,100.,.0800018,859,100.,.0676083
860,100.,.0676083,861,100.,.0800018,862,100.,.0676083
863,100.,.0676083,864,100.,.0800018,865,100.,.0985149
866,100.,.0432693,867,100.,.0370880,868,100.,.0432693
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 8)
869,100.,.0432693,870,100.,.0370880,871,100.,.0432693
872,100.,.0985149,873,100.,.0800018,874,100.,.0676083
875,100.,.0676083,876,100.,.0800018,877,100.,.0676083
878,100.,.0676083,879,100.,.0800018,880,100.,.0985149
881,100.,.0985149,882,100.,.0800018,883,100.,.0676083
884,100.,.0676083,885,100.,.0800018,886,100.,.0676083
887,100.,.0676083,888,100.,.0800018,889,100.,.0985149
890,100.,.0432693,891,100.,.0370880,892,100.,.0432693
REM FLUID TEMPERATURE ARITHMETIC NODES
617,116.,-1.,616,119.,-1.,615,119.,-1.,614,122.,-1.
613,122.,-1.,612,125.,-1.,611,125.,-1.,610,128.,-1.
609,128.,-1.,608,131.,-1.,607,131.,-1.,606,134.,-1.
605,134.,-1.,604,137.,-1.,603,137.,-1.,602,140.,-1.
635,116.,-1.,634,119.,-1.,633,119.,-1.,632,122.,-1.
631,122.,-1.,630,125.,-1.,629,125.,-1.,628,128.,-1.
627,128.,-1.,626,131.,-1.,625,131.,-1.,624,134.,-1.
623,134.,-1.,622,137.,-1.,621,137.,-1.,620,140.,-1.
653,116.,-1.,652,119.,-1.,651,119.,-1.,650,122.,-1.
649,122.,-1.,648,125.,-1.,647,125.,-1.,646,128.,-1.
645,128.,-1.,644,131.,-1.,643,131.,-1.,642,134.,-1.
641,134.,-1.,640,137.,-1.,639,137.,-1.,638,140.,-1.
REM FLUID TEMPERATURE NODES - MIXING (SYSTEMS 1,2,3)
618,116.,-1.,636,116.,-1.,654,116.,-1.
REM FLUID TEMPERATURE NODES - BOUNDARY (SYSTEMS 1,2,3)
-601,190.,-619,190.,-637,190.,
REM FLUID PRESSURE NODES (SYSTEM 1)
-501,,,-502,,,-503,,,-504,,,-505,,,-506,,,-507,,,-508,,
-509,,,-510,,,-511,,,-512,,,-513,,,-514,,,-515,,,-516,,
-517,,,-518,,,-519,,,-520,,,-521,,,-522,,,-523,,,-524,,
-525,,,-526,,,-527,0.
REM FLUID PRESSURE NODES (SYSTEM 2)
-528,,,-529,,,-530,,,-531,,,-532,,,-533,,,-534,,,-535,,
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-544,,,-545,,,-546,,,-547,,,-548,,,-549,,,-550,,,-551,,
-552,,,-553,,,-554,0.
REM FLUID PRESSURE NODES (SYSTEM 3)
-555,,,-556,,,-557,,,-558,,,-559,,,-560,,,-561,,,-562,,
-563,,,-564,,,-565,,,-566,,,-567,,,-568,,,-569,,,-570,,
-571,,,-572,,,-573,,,-574,,,-575,,,-576,,,-577,,,-578,,
-579,,,-580,,,-581,0.
REM EDGE SINK TEMPERATURE NODE FOR PANELS 1 TO 8
-893,-150.,
REM ENVIRONMENTAL SINK TEMPERATURE NODES FOR PANELS 1 TO 8
-901,-460.,-902,-460.,-903,-460.,-904,-460.,-905,-460.,
-906,-460.,-907,-460.,-908,-460.,
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BCD 3CONDUCTOR DATA
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REM SOLID CONDUCTOR - NUMBER 701
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$CND0040
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$CND0070
$CND0080
$PANEL 1
$PANEL 2
$PANEL 3
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797,798,798,799,818,819,819,820	\$PANEL 5	\$CND0100
821,822,822,823,842,843,843,844	\$PANEL 6	\$CND0110
845,846,846,847,866,867,867,868	\$PANEL 7	\$CND0120
869,870,870,871,890,891,891,892,.1996911	\$PANEL 8	\$CND0130
REM SOLID CONDUCTOR - NUMBER 702		\$CND0140
702,701,704,703,712,713,722,721,724	\$PANEL 1	\$CND0150
725,728,727,736,737,746,745,748	\$PANEL 2	\$CND0160
749,752,751,760,761,770,769,772	\$PANEL 3	\$CND0170
773,776,775,784,785,794,793,796	\$PANEL 4	\$CND0180
797,800,799,809,809,818,817,820	\$PANEL 5	\$CND0190
821,824,823,832,833,842,841,844	\$PANEL 6	\$CND0200
845,848,847,856,857,866,865,868	\$PANEL 7	\$CND0210
869,872,871,880,881,890,889,892,.1767663	\$PANEL 8	\$CND0220
REM SOLID CONDUCTOR - NUMBER 703		\$CND0230
703,701,705,702,708,703,711,714,722,717,723,720,724	\$PNL1	\$CND0240
725,729,726,732,727,735,738,746,741,747,744,748	\$PNL2	\$CND0250
749,753,750,756,751,759,762,770,765,771,768,772	\$PNL3	\$CND0260
773,777,774,780,775,783,786,794,789,795,792,796	\$PNL4	\$CND0270
797,801,798,804,799,807,810,818,813,819,816,820	\$PNL5	\$CND0280
821,825,822,828,823,831,834,842,837,843,840,844	\$PNL6	\$CND0290
845,849,846,852,847,855,858,866,861,867,864,868	\$PNL7	\$CND0300
869,873,870,876,871,879,882,890,885,891,888,892,.090127	\$PNL8	\$CND0310
REM SOLID CONDUCTOR - NUMBER 704		\$CND0320
704,701,706,702,707,702,709,703,710	\$ PANEL 1	\$CND0330
715,722,716,723,718,723,719,724	\$ PANEL 1	\$CND0340
725,730,726,731,726,733,727,734	\$ PANEL 2	\$CND0350
739,746,740,747,742,747,743,748	\$ PANEL 2	\$CND0360
749,754,750,755,750,757,751,758	\$ PANEL 3	\$CND0370
763,770,764,771,766,771,767,772	\$ PANEL 3	\$CND0380
773,778,774,779,774,781,775,782	\$ PANEL 4	\$CND0390
787,794,788,795,790,795,791,796	\$ PANEL 4	\$CND0400
797,802,798,803,798,805,799,806	\$ PANEL 5	\$CND0410
811,818,812,819,814,819,815,820	\$ PANEL 5	\$CND0420
821,826,822,827,822,829,823,830	\$ PANEL 6	\$CND0430
835,842,836,843,838,843,839,844	\$ PANEL 6	\$CND0440
845,850,846,851,846,853,847,854	\$ PANEL 7	\$CND0450
859,866,860,867,862,867,863,868	\$ PANEL 7	\$CND0460
869,874,870,875,870,877,871,878	\$ PANEL 8	\$CND0470
883,890,884,891,886,891,887,892,.121294	\$ PANEL 8	\$CND0480
REM SOLID CONDUCTOR - NUMBER 705		\$CND0490
705,704,705,711,712,713,714,720,721	\$PANEL 1	\$CND0500
728,729,735,736,737,738,744,745	\$PANEL 2	\$CND0510
752,753,759,760,761,762,768,769	\$PANEL 3	\$CND0520
776,777,783,784,785,786,792,793	\$PANEL 4	\$CND0530
800,801,807,808,809,810,816,817	\$PANEL 5	\$CND0540
824,825,831,832,833,834,840,841	\$PANEL 6	\$CND0550
848,849,855,856,857,858,864,865	\$PANEL 7	\$CND0560
872,873,879,880,881,882,888,889,3.111299	\$PANEL 8	\$CND0570
REM SOLID CONDUCTOR - NUMBER 706		\$CND0580
706,705,706,707,708,708,709,710,711	\$PANEL 1	\$CND0590
714,715,716,717,717,718,719,720	\$PANEL 1	\$CND0600
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753,754,755,756,756,757,758,759	\$PANEL 3	\$CND0630
762,763,764,765,765,766,767,768	\$PANEL 3	\$CND0640
777,778,779,780,780,781,782,783	\$PANEL 4	\$CND0650
786,787,788,789,789,790,791,792	\$PANEL 4	\$CND0660
801,802,803,804,804,805,806,807	\$PANEL 5	\$CND0670
810,811,812,813,813,814,815,816	\$PANEL 5	\$CND0680
825,826,827,828,828,829,830,831	\$PANEL 6	\$CND0690
834,835,836,837,837,838,839,840	\$PANEL 6	\$CND0700
849,850,851,852,852,853,854,855	\$PANEL 7	\$CND0710
858,859,860,861,861,862,863,864	\$PANEL 7	\$CND0720



	873,874,875,876,876,877,878,879	\$PANEL 8	\$CND0730
	882,883,884,885,885,886,887,888,3.927239	\$PANEL 8	\$CND0740
REM	SOLID CONNECTOR - NUMBER 707		\$CND0750
	707,706,707,709,710,715,716,718,719	\$PANEL 1	\$CND0760
	730,731,733,734,739,740,742,743	\$PANEL 2	\$CND0770
	754,755,757,758,763,764,766,767	\$PANEL 3	\$CND0780
	778,779,781,782,787,789,790,791	\$PANEL 4	\$CND0790
	802,803,805,806,811,812,814,815	\$PANEL 5	\$CND0800
	826,827,829,830,835,836,838,839	\$PANEL 6	\$CND0810
	850,851,853,854,859,860,862,863	\$PANEL 7	\$CND0820
	874,875,877,878,883,884,886,887,3.422037	\$PANEL 8	\$CND0830
REM	SOLID CONDUCTOR - NUMBER 708		\$CND0840
	708,704,713,712,721,728,737,736,745	\$PANELS 1-2	\$CND0850
	752,761,760,769,776,785,784,793	\$PANELS 3-4	\$CND0860
	800,809,808,817,824,833,832,841	\$PANELS 5-6	\$CND0870
	849,857,856,865,872,881,880,889,.106059	\$PANEL 8	\$CND0880
RFM	SOLID CONDUCTOR - NUMBER 709		\$CND0890
	709,705,714,708,717,711,720	\$PANEL 1	\$CND0900
	729,738,732,741,735,744	\$PANEL 2	\$CND0910
	753,762,756,765,759,768	\$PANEL 3	\$CND0920
	777,786,790,789,783,792	\$PANEL 4	\$CND0930
	801,810,804,813,807,816	\$PANEL 5	\$CND0940
	825,834,828,837,831,840	\$PANEL 6	\$CND0950
	849,858,852,861,855,864	\$PANEL 7	\$CND0960
	873,882,876,885,879,888,.1829098	\$PANEL 8	\$CND0970
REM	SOLID CONDUCTOR - NUMBER 710		\$CND0980
	710,706,715,707,716,709,718,710,719	\$PANEL 1	\$CND0990
	730,739,731,740,733,742,734,743	\$PANEL 2	\$CND1000
	754,763,755,764,757,766,758,767	\$PANEL 3	\$CND1010
	778,787,779,788,781,790,782,791	\$PANEL 4	\$CND1020
	802,811,803,812,805,814,806,815	\$PANEL 5	\$CND1030
	826,835,827,836,829,838,830,839	\$PANEL 6	\$CND1040
	850,859,851,860,853,862,854,863	\$PANEL 7	\$CND1050
	874,883,875,884,877,886,878,887,.0727762	\$PANEL 8	\$CND1060
REM	SOLID CONDUCTOR - NUMBER 711		
	711,701,893,702,893,703,893,712,893,721,893,724,893,723,893		
	722,893,713,893,704,893	\$PANEL 1	
	725,893,726,893,727,893,736,893,745,893,748,893,747,893		
	746,893,737,893,728,893	\$PANEL 2	
	749,893,750,893,751,893,760,893,769,893,772,893,771,893		
	770,893,761,893,752,893	\$PANEL 3	
	773,893,774,893,775,893,784,893,793,893,796,893,795,893		
	794,893,785,893,776,893	\$PANEL 4	
	797,893,798,893,799,893,808,893,817,893,820,893,819,893		
	818,893,809,893,800,893	\$PANEL 5	
	821,893,822,893,823,893,832,893,841,893,844,893,843,893		
	842,893,833,893,824,893	\$PANEL 6	
	845,893,846,893,847,893,856,893,865,893,868,893,867,893		
	866,893,857,893,848,893	\$PANEL 7	
	869,893,870,893,871,893,880,893,889,893,892,893,891,893		
	890,893,881,893,872,893,.0109890	\$PANEL 8	
REM			\$CND1070
REM	CONVECTION CONDUCTORS		\$CND1080
REM			\$CND1090
	1001,602,708,.1002,603,717,.1003,604,735,.1004,605,744,		\$CND1100
	1005,606,753,.1006,607,762,.1007,608,780,.1008,609,789,		\$CND1110
	1009,610,807,.1010,611,816,.1011,612,825,.1012,613,834,		\$CND1120
	1013,614,852,.1014,615,861,.1015,616,879,.1016,617,888,		\$CND1130
	1017,620,711,.1018,621,720,.1019,622,729,.1020,623,738,		\$CND1140
	1021,624,756,.1022,625,765,.1023,626,783,.1024,627,792,		\$CND1150
	1025,628,801,.1026,629,810,.1027,630,828,.1028,631,837,		\$CND1160
	1029,632,855,.1030,633,864,.1031,634,873,.1032,635,882,		\$CND1170
	1033,638,705,.1034,639,714,.1035,640,732,.1036,641,741,		\$CND1180
	1037,642,759,.1038,643,768,.1039,644,777,.1040,645,786,		\$CND1190



	1041,646,804,,1042,647,813,,1043,648,831,,1044,649,840,	\$CND1200
	1045,650,849,,1046,651,858,,1047,652,876,,1048,653,885,	\$CND1210
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REM	PRESSURE CONDUCTORS (SYSTEM 1)	\$CND1230
REM		\$CND1240
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REM	PRESSURE CONDUCTORS (SYSTEM 2)	\$CND1270
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		\$CND1290
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		\$CND1320



REM PRESSURE CONDUCTORS (SYSTEM 3)
REM

\$CND1330
\$CND1340

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\$CND1390
\$CND1400

REM
REM FLUID FLOW CONDUCTORS (SYSTEM 1)
REM

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\$CND1420
\$CND1430
\$CND1440
\$CND1450

REM
REM FLUID FLOW CONDUCTORS (SYSTEM 2)
REM

619,-619,620,
620,-620,621,
621,-621,622,
622,-622,623,
623,-623,624,
624,-624,625,
625,-625,626,
626,-626,627,
627,-627,628,
628,-628,629,
629,-629,630,



630,-630,631,
631,-631,632,
632,-632,633,
633,-633,634,
634,-634,635,
635,-635,636,
636,-629,636,
\$CND1470
\$CND1480
\$CND1490
\$CND1500
REM
RFM FLUID FLOW CONDUCTORS (SYSTEM 3)
REM
637,-637,638,
638,-638,639,
639,-639,640,
640,-640,641,
641,-641,642,
642,-642,643,
643,-643,644,
644,-644,645,
645,-645,646,
646,-646,647,
647,-647,648,
648,-648,649,
649,-649,650,
650,-650,651,
651,-651,652,
652,-652,653,
653,-653,654,
654,-647,654,
\$CND1520
\$CND1530
\$CND1540
REM
REM RADIATION CONDUCTOR - NUMBER 901
-901,701,901,703,901,722,901,724,901
725,902,727,902,746,902,748,902
749,903,751,903,770,903,772,903
773,904,775,904,794,904,796,904
797,905,799,905,818,905,820,905
821,906,823,906,842,906,844,906
845,907,847,907,866,907,868,907
869,908,871,908,890,908,892,908,.229827E-9
\$PANEL 1 \$CND1550
\$PANEL 2 \$CND1560
\$PANEL 3 \$CND1570
\$PANEL 4 \$CND1580
\$PANEL 5 \$CND1590
\$PANEL 6 \$CND1600
\$PANEL 7 \$CND1610
\$PANEL 8 \$CND1620
\$CND1630
\$CND1640
\$CND1650
REM
REM RADIATION CONDUCTOR - NUMBER 902
REM
-902,702,901,723,901,726,902,747,902
750,903,771,903,774,904,795,904
798,905,819,905,822,906,843,906
846,907,867,907,870,908,891,908,.196995E-9
\$PANEL 1-2 \$CND1660
\$PANEL 3-4 \$CND1670
\$PANEL 5-6 \$CND1680
\$PANEL 7-8 \$CND1690
\$CND1700
\$CND1710
\$CND1720
REM
REM RADIATION CONDUCTOR - NUMBER 903
REM
-903,704,901,712,901,713,901,721,901
728,902,736,902,737,902,745,902
752,903,760,903,761,903,769,903
776,904,784,904,785,904,793,904
800,905,808,905,809,905,817,905
824,906,832,906,833,906,841,906
848,907,856,907,857,907,865,907
872,908,880,908,881,908,889,908,.523268E-9
\$PANEL 1 \$CND1730
\$PANEL 2 \$CND1740
\$PANEL 3 \$CND1750
\$PANEL 4 \$CND1760
\$PANEL 5 \$CND1770
\$PANEL 6 \$CND1780
\$PANEL 7 \$CND1790
\$PANEL 8 \$CND1800
\$CND1810
\$CND1820
\$CND1830
REM
REM RADIATION CONDUCTOR - NUMBER 904
REM
-904,705,901,706,901,711,901,712,901,717,901,718,901,719,901,720,901,721,901,722,901,723,901,724,901,725,902,726,902,727,902,728,902,729,902,730,902,731,902,732,902,733,902,734,902,735,902,736,902,737,902,738,902,739,902,740,902,741,902,742,902,743,902,744,902,745,902,746,902,747,902,748,902,749,902,750,902,751,902,752,902,753,902,754,902,755,902,756,902,757,902,758,902,759,902,760,902,761,902,762,902,763,902,764,902,765,902,766,902,767,902,768,902,769,902,770,902,771,902,772,902,773,902,774,902,775,902,776,902,777,902,778,902,779,902,780,902,781,902,782,902,783,902,784,902,785,902,786,902,787,902,788,902,789,902,790,902,791,902,792,902,793,902,794,902,795,902,796,902,797,902,798,902,799,902,800,902,801,902,802,902,803,902,804,902,805,902,806,902,807,902,808,902,809,902,810,902,811,902,812,902,813,902,814,902,815,902,816,902,817,902,818,902,819,902,820,902,821,902,822,902,823,902,824,902,825,902,826,902,827,902,828,902,829,902,830,902,831,902,832,902,833,902,834,902,835,902,836,902,837,902,838,902,839,902,840,902,841,902,842,902,843,902,844,902,845,902,846,902,847,902,848,902,849,902,850,902,851,902,852,902,853,902,854,902,855,902,856,902,857,902,858,902,859,902,860,902,861,902,862,902,863,902,864,902,865,902,866,902,867,902,868,902,869,902,870,902,871,902,872,902,873,902,874,902,875,902,876,902,877,902,878,902,879,902,880,902,881,902,882,902,883,902,884,902,885,902,886,902,887,902,888,902,889,902,890,902,891,902,892,902,893,902,894,902,895,902,896,902,897,902,898,902,899,902,900,902,901,902,902,902,903,902,904,902,905,902,906,902,907,902,908,902,909,902,910,902,911,902,912,902,913,902,914,902,915,902,916,902,917,902,918,902,919,902,920,902,921,902,922,902,923,902,924,902,925,902,926,902,927,902,928,902,929,902,930,902,931,902,932,902,933,902,934,902,935,902,936,902,937,902,938,902,939,902,940,902,941,902,942,902,943,902,944,902,945,902,946,902,947,902,948,902,949,902,950,902,951,902,952,902,953,902,954,902,955,902,956,902,957,902,958,902,959,902,960,902,961,902,962,902,963,902,964,902,965,902,966,902,967,902,968,902,969,902,970,902,971,902,972,902,973,902,974,902,975,902,976,902,977,902,978,902,979,902,980,902,981,902,982,902,983,902,984,902,985,902,986,902,987,902,988,902,989,902,990,902,991,902,992,902,993,902,994,902,995,902,996,902,997,902,998,902,999,902,1000,902
\$PANEL 1 \$CND1850
\$PANEL 2 \$CND1860
\$PANEL 3 \$CND1870
\$PANEL 4 \$CND1880
\$PANEL 5 \$CND1890



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825,906,828,906,831,906,834,906,837,906,840,906    $PANEL 6$CND1890
849,907,852,907,855,907,858,907,861,907,864,907    $PANEL 7$CND1900
873,908,876,908,879,908,882,908,885,908            $CND1910
888,908,,.270036E-9                                $CND1920
REM                                                    $CND1930
PEM RADIATION CONDUCTOR - NUMBER 905                $CND1940
REM                                                    $CND1950
-905,706,901,707,901,709,901,710,901              $PANEL 1$CND1960
715,901,716,901,718,901,719,901                    $PANEL 1$CND1970
730,902,731,902,733,902,734,902                    $PANEL 2$CND1980
739,902,740,902,742,902,743,902                    $PANEL 2$CND1990
754,903,755,903,757,903,758,903                    $PANEL 3$CND2000
763,903,764,903,766,903,767,903                    $PANEL 3$CND2010
778,904,779,904,781,904,782,904                    $PANEL 4$CND2020
787,904,788,904,790,904,791,904                    $PANEL 4$CND2030
802,905,803,905,805,905,806,905                    $PANEL 5$CND2040
811,905,812,905,814,905,815,905                    $PANEL 5$CND2050
826,906,827,906,829,906,830,906                    $PANEL 6$CND2060
835,906,836,906,838,906,839,906                    $PANEL 6$CND2070
850,907,851,907,853,907,854,907                    $PANEL 7$CND2080
859,907,860,907,862,907,863,907                    $PANEL 7$CND2090
874,908,875,908,877,908,878,908                    $PANEL 8$CND2100
883,908,884,908,886,908,887,908,,.359122E-9        $PANEL 8$CND2110
REM                                                    $CND2120
END                                                    $CND2130
BCD 3CONSTANTS DATA                                $CNS0010
TIMEND, 6.2, OUTPUT, 0.05
1,3.6,2.28,3.15,4.10,5.27 $K5 IS NO PRESSURE COND PEP SYSTEM $CNS0030
6,85,,7,0.0001,8,0.0001    $ WATER GLYCOL FLOW RATE
9,0,10,0,11,0              $ BYPASS OPTION
REM CONSTANTS FOR INCIDENT HEAT -- PANELS 1-8        $CNS0060
12,,13,,14,,15,39,,16,83,,17,82,,18,40,,19,         $CNS0070
20,24 $ NUMBER OF NODES PER PANEL                  $CNS0080
21,.374223E-3 $ VOLUME OF FLUID CAPACITANCE NODES $CNS0090
22,16 $ NO. OF NODES PER SYSTEM WITH CAPACITANCE VALUES $CNS0100
23,3.60                                              $CNS0110
REM -K22 IS NO. OF CONVECTION CONDUCTORS PER SYSTEM $CNS0120
24,18 $ NO. OF THERMAL FLUID FLOW CONDUCTORS PER SYSTEM $CNS0130
25,.6944444E-2 $ CONVERSION FROM PSF TO PSI         $CNS0140
REM CONSTANTS USED IN OUTPUT CALLS                  $CNS0150
26,,27,16,28,,29, STMP,30,192,31,701,32,,33,NO USE$
REM MULTIPLYING FACTORS FOR PRESSURE CONDUCTORS     $CNS0170
501,255.91,502,108.265,503,108.265,504,30.57,505,108.265 $CNS0180
506,108.265,507,53.03,508,108.265,509,108.265,510,65.726 $CNS0190
511,108.265,512,108.265,513,49.71,514,108.265,515,108.265 $CNS0200
516,33.01,517,108.265,518,108.265,519,59.7692,520,108.265 $CNS0210
521,108.265,522,58.0113,523,108.265,524,108.265,525,36.0373 $CNS0220
526,55.2666,527,148.1534,528,285.9462,529,108.265 $CNS0230
530,108.265,531,30.7636,532,108.265,533,108.265,534,67.6798 $CNS0240
535,108.265,536,108.265,537,49.71,538,108.265,539,108.265 $CNS0250
540,49.4174,541,108.265,542,108.265,543,66.5079,544,108.265 $CNS0260
545,108.265,546,43.9479,547,108.265,548,108.265,549,59.3824 $CNS0270
550,108.265,551,108.265,552,47.0735,553,68.8417,554,159.4818 $CNS0280
555,295.3176,556,108.265,557,108.265,558,46.7802,559,108.265 $CNS0290
560,108.265,561,52.0539,562,108.265,563,108.265,564,50.296 $CNS0300
565,108.265,566,108.265,567,65.2422,568,108.265,569,108.265 $CNS0310
570,43.5577,571,108.265,572,108.265,573,44.4363,574,108.265 $CNS0320
575,108.265,576,73.8325,577,108.265,578,108.265,579,40.9204 $CNS0330
580,68.8717,581,158.5055 $CNS0340
REM COMPRESSED PRESSURE CONDUCTORS                  $CNS0350
582,,583,,584,,585,,586,,587,,588,,589,,590,,591,,592,,593, $CNS0360
594,0,,595,7 $CNS0370
598,150.0 $INITIAL SOLID NODE TEMP
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599,192 $ NO. OF SOLID TEMPERATURE NODES $CNS0390
600, 6.2
REM CONSTANTS 601 TO 681 * 4/WP AND ARE USED IN RE NO. COMPUTATN $CNS0410
601,66.427,602,37.619,603,37.619,604,50.087,605,37.619 $CNS0420
606,37.619,607,50.087,608,37.619,609,37.619,610,50.087 $CNS0430
611,37.619,612,37.619,613,50.087,614,37.619,615,37.619 $CNS0440
616,50.087,617,37.619,618,37.619,619,50.087,620,37.619 $CNS0450
621,37.619,622,50.087,623,37.619,624,37.619,625,50.087 $CNS0460
626,50.087,627,50.087,628,66.427,629,37.619,630,37.619 $CNS0470
631,50.087,632,37.619,633,37.619,634,50.087,635,37.619 $CNS0480
636,37.619,637,50.087,638,37.619,639,37.619,640,50.087 $CNS0490
641,37.619,642,37.619,643,50.087,644,37.619,645,37.619 $CNS0500
646,50.087,647,37.619,648,37.619,649,50.087,650,37.619 $CNS0510
651,37.619,652,50.087,653,50.087,654,50.087,655,66.427 $CNS0520
656,37.619,657,37.619,658,50.087,659,37.619,660,37.619 $CNS0530
661,50.087,662,37.619,663,37.619,664,50.087,665,37.619 $CNS0540
666,37.619,667,50.087,668,37.619,669,50.087,670,50.087 $CNS0550
671,37.619,672,37.619,673,50.087,674,37.619,675,37.619 $CNS0560
676,50.087,677,37.619,678,37.619,679,50.087,680,50.087 $CNS0570
681,50.087,682,66.427,683,66.427,684,66.427 $CNS0580
701,.080311,702,0.,703,0.,704,.042633,705,0.,706,0. $CNS0590
707,.042633,708,0.,709,0.,710,.042633,711,0.,712,0. $CNS0600
713,.042633,714,0.,715,0.,716,.042633,717,0.,718,0. $CNS0610
719,.042633,720,0.,721,0.,722,.042633,723,0.,724,0. $CNS0620
725,.023644,726,.0023271,727,.0472876,728,.080311 $CNS0630
729,0.,730,0.,731,.042633,732,0.,733,0.,734,.042633,735,0. $CNS0640
736,0.,737,.042633,738,0.,739,0.,740,.042633,741,0.,742,0. $CNS0650
743,.042633,744,0.,745,0.,746,.042633,747,0.,748,0. $CNS0660
749,.042633,750,0.,751,0.,752,.023644,753,.0023271 $CNS0670
754,.0472876,755,.080311,756,0.,757,0.,758,.042633,759,0. $CNS0680
760,0.,761,.042633,762,0.,763,0.,764,.042633,765,0.,766,0. $CNS0690
767,.042633,768,0.,769,0.,770,.042633,771,0.,772,0. $CNS0700
773,.042633,774,0.,775,0.,776,.042633,777,0.,778,0. $CNS0710
779,.023644,780,.0023271,781,.0472876 $CNS0720
801,.802,.803, $ FLUID HEAT LOSS PER SYSTEM $CNS0730
804,.0265823$(WP/4) FOR PANEL TUBES $CNS0740
REM CONSTANTS FOR GR NUMBER * (WP/4)*(X/D) $CNS0750
805,.984934,806,4.725,807,.984934,808,4.725 $CNS0760
809,.984934,810,4.725,811,.984934,812,4.725 $CNS0770
813,.984934,814,4.725,815,.984934,816,4.725 $CNS0780
817,.984934,818,4.725,819,.984934,820,4.725 $CNS0790
821,.822,.823, $ INVERSE FLOW RATE $CNS0800
824,.825,.826, $ SYSTEM PRESSURE DROP $CNS0810
827,150.,828,150.,829,150. $ PREVIOUS TSRC
830, 22., 831, 22., 832, 22. $ MASS OF KOH
833,.73,834,.73,835,.73 $ PERCENT KOH IN STACK
836, 160., 837, 160., 838, 160. $ TCE
839, 85.8 $ GAS CONSTANT - WATER
840, 767. $ GAS CONSTANT H2
841,180.,842,180.,843,180. $ VOLUMETRIC FLOW RATE
844,340.,845,340.,846,340. $ STACK INLET TEMP
847,420.,848,420.,849,420. $ STACK OUTLET TEMPS
850,-.60, 851,-.60, 852,-.60 $ PC H2O PROD. IN STACK
853, 0.023 $ H2O PRODUCTION RATE
854,30.,855,0.,856,0. $ CURRENT - AMPS
857, 0.01 $ ACCEPTABLE ERROR FOR RATE
858,.859,.860, $ CELL VOLTAGE
861, 0. $ NOT USED
862, 30. $ MCP OF STACK
863, 0. $ NOT USED
864,2.43E-3 $VOL,FT**3,RAD OUT TO REG COLD INLET
865,1.545E-2 $VOL,FT**3,REG COLD SIDE
866,3.76E-3 $VOL,FT**3,COND GLYCOL SIDE
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867,4.63E-3    $VOL,FT**3,COND OUTLET TO REG. INLET
868,2.431E-2    $    ,FT**3,SECONDARY REG HOT SIDE
869,2.26E-3    $VOL,FT**3,REG. TO RAD INLET
870,160.,871,160.,872,160.    $TCE, PREVIOUS TIME STEP
873,1,874,1,875,1    $INTEGER POINTER FOR SEC RP VLV
876.,877.,878,    $    TEMP COND INLET
879.,5,880.,5,881.,5    $SECONDARY BYPASSED FRACTION
882,130.,883,130.,884,130.    $SEC REG COLD OUTLET
885.,95    $BYPASS FRACTION CUTOFF VALUE
886.,887.,888,    $INVERSE FLOW RATES
889,0.25    $REG DELAY ADJ FACTOR
890,100.,891,100.,892,100.    $REG COLD SIDE INLET
893,175.,894,175.,895,175.    $COND GLY OUT TEMP
896,175.,897,175.,898,175.    $SEC REG HOT SIDE INLET
899,100.,900,100.,901,100.    $SEC REG HOT SIDE OUTLET
902,1.,903,1.,904,1.    $    INTEGERS USED FOR DO LOOPS
905.,906.,907,    $    INTEGERS USED FOR BY PASS
908,150.07,909,150.07,910,150.07    $    COND GLY INLET TEMP
911, 1.    $COND HEAT BAL TOLERANCE
912,200    $ARRAY IC
913,199    $ARRAY IC
914,20    $ARRAY IC
915,40    $ARRAY IC
916,30    $ARRAY IC
917.,918.,919,    $    POWER - WATTS
920,77.29,921,77.29,922,77.29    $    H2O SPECIFIC VOLUME
923.,924.,925,    $    PERCENT BY-PASS PRIMARY
926.,927.,928,    $    STACK EXIT PRESSURE
929.,930.,931,    $    PERCENT KOH
932.,933.,934,    $    H2O PRESSURE
935.,936.,937,    $    ENTHALPY OF STEAM
938.,939.,940,    $    INITIAL PRESSURE
941.,942.,943,    $    INITIAL SPECIFIC VOLUME
944,70.,945,70.,946,70.    $    AMBIENT TEMP DEG F
947,0.00257    $    H2 PRODUCTION RATE
948,5772.79    $LOWER HEATING VALUE, H2
949,6824.42    $HIGHER HEATING VALUE, H2
950,0.2    $ERROR FOR STACK INLET
951, 5.    $INITIAL COND TEMP INCREMENT
952, +1    $INTEGER INDICATOR FOR COND IMBAL
953,1.0    $ERROR FOR HEAT BALANCE
954,0.2    $ERROR FOR STACK INLET TEMP
955.,956.,957,    $WATER CONDENSED-LB/HR
958.,959.,960,    $STACK WATER STORAGE RATE
961,0.5,962,0.5,963,0.5    $    SEC RP VLV STAT POS
964,530.    $    O2 INLET TEMP - DEGR
965,530.    $    H2 INLET TEMP - DEGR
966,0.48    $    O2 FLOW RATE - LB/HR
967,0.06    $    H2 FLOW RATE - LB/HR
968,100.,969,100.,970,100.    $    O2 REACTANT TEMP TO STACK
971,100.,972,100.,973,100.    $    H2 REACTANT TEMP TO STACK
974.,975.,976,    $    FLOW RATE FIX-UP

END
BCD 3ARRAY DATA
1    $ DENSITY OF GLYCOL-WATER    LBM/FT**3
-460.,75.09,-50.,69.54,-40.,69.4,-30.,69.25,-20.,69.1
-10.,68.93,0.,68.76,10.,68.58,20.,68.4,30.,68.2,40.,68.1
50.,67.83,60.,67.63,70.,67.43,80.,67.22,90.,67.,100.,66.78
110.,66.56,120.,66.34,130.,66.1,140.,65.85,150.,65.61
160.,65.35,170.,65.1,180.,64.84,190.,64.57,200.,64.23
250.,62.79,300.,61.23,350.,59.61,END
2    $ CONDUCTIVITY OF GLYCOL-WATER    BTU/HR*FT*F
-460.,.2279,-50.,.2279,-40.,.2279,-30.,.2278,-20.,.2277
$CNS1050
$ARRO010
$ARRO020
$ARRO030
$ARRO040
$ARRO050
$ARRO060
$ARRO070
$ARRO080
$ARRO090
$ARRO100

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-10...2275.0...2273.10...2270.20...2266.30...2262.40...2258 $ARR0110
50...2252.60...2246.70...2240.80...2233.90...2225.100...2217 $ARR0120
110...2208.120...2199.130...2189.140...2178.150...2167 $ARR0130
160...2156.170...2143.180...2130.190...2117.200...2103 $ARR0140
340...1844,END $ARR0150
3 $ SPECIFIC HEAT OF GLYCOL-WATER RTU/LBM*F $ARR0160
-460...033,-50...606,-40...618,-30...631,-20...643 $ARR0170
-13...655,0...666,10...677,20...688,30...698,40...708 $ARR0180
50...718,60...729,70...737,80...746,90...754,100...762 $ARR0190
110...770,120...777,130...784,140...791,150...797,160...803 $ARR0200
170...809,180...814,190...819,200...824,230...84 $ARR0210
270...86,310...878,END $ARR0211
4 $ VISCOSITY OF GLYCOL-WATER E-3 LBM/FT*SEC $ARR0220
-460...500000,-50...245,-40...135,-30...80,-20...51.9,-10. $ARR0230
34...0...24.5,10...16.5,20...12.2,30...9.3,40...7.3,50...5.75 $ARR0240
60...4.65,70...3.75,80...3.05,90...2.58,100...2.08,110...1.87 $ARR0250
120...1.61,130...1.4,140...1.22,150...1.11,160...96,170...86 $ARR0260
180...77,190...69,200...625,250...406,300...303 $ARR0270
350...216,END $ARR0271
5,SPACE,28,END $ARR0280
6,SPACE,28,END $ARR0290
7,SPACE,28,END $ARR0300
8,SPACE,81,END $ARR0310
9,SPACE,54,END $ARR0320
10 $BYPASSED FRACTION -- SECONDARY BP VLV-ASCENDING TCE
157...0.0,157.25,0.165,157.5,0.245,157.75,0.3,158...0.34
158.25,0.38,158.5,0.41,158.75,0.43,159...0.445,159.25,0.46
159.5,0.47,159.75,0.474,160...0.48,160.25,0.485,160.5,0.49
160.75,0.493,161...0.498,161.25,0.5,161.5,0.51,161.75,0.52
162...0.534,162.25,0.555,162.5,0.58,162.75,0.615,163...0.65
163.25,0.71,163.5,0.8,163.75,0.935,164...1.0,END
11 $BYPASSED FRACTION -- SECONDARY BP VLV-DESCENDING TCE
154...0.0,154.25,0.12,154.5,0.195,154.75,0.255,155...0.31
155.25,0.365,155.5,0.4,155.75,0.425,156...0.44,156.25,0.457
156.5,0.467,156.75,0.475,157.0,0.48,157.25,0.485,157.5,0.488
157.75,0.492,158...0.5,158.25,0.506,158.5,0.512,158.75,0.522
159...0.535,159.25,0.554,159.5,0.58,159.75,0.62,160...0.665
160.25,0.74,160.5,0.88,160.75,0.94,161...1.0,END
12...145833...125000...145833...332031...171347...227875...227875 $ARR0350
...171347...227875...227875...171347...332031...171347 $ARR0360
...227875...227875...171347...227875...227875...171347...332031 $ARR0370
...145833...125000...145833,END $ARR0380
REM THE FOLLOWING ARRAYS PROVIDE FOR VARIABLE INCIDENT HEAT FLUX $ARR0390
13 $ INCIDENT HEAT FOR PANEL 1 - BTU/HR FT**2 $ARR0400
0.00,07.09,0.05,15.67,0.10,23.90,0.15,31.45,0.20,38.00 $PANEL1
0.25,43.30,0.30,47.13,0.35,49.33,0.40,49.81,0.45,48.55 $PANEL1
0.50,45.60,0.55,41.09,0.60,35.20,0.65,28.16,0.70,20.27 $PANEL1
0.75,11.84,0.80,07.09,1.55,07.09,END $PANEL1
14 $ INCIDENT HEAT FOR PANEL 2 - BTU/HR FT**2 $ARR0420
0.00,00.27,0.05,15.58,0.10,30.26,0.15,43.73,0.20,55.43 $PANEL2
0.25,64.88,0.30,71.71,0.35,75.63,0.40,76.48,0.45,74.24 $PANEL2
0.50,68.98,0.55,60.94,0.60,50.42,0.65,37.86,0.70,23.77 $PANEL2
0.75,08.74,0.80,00.27,1.55,00.27,END $PANEL2
15 $ INCIDENT HEAT FOR PANEL 3 - BTU/HR FT**2 $ARR0440
0.00,00.00,0.05,16.82,0.10,32.96,0.15,47.75,0.20,60.61 $PANEL3
0.25,71.00,0.30,78.50,0.35,82.81,0.40,83.75,0.45,81.28 $PANEL3
0.50,75.51,0.55,66.66,0.60,55.11,0.65,41.31,0.70,25.83 $PANEL3
0.75,09.31,0.80,00.00,1.55,00.00,END $PANEL3
16 $ INCIDENT HEAT FOR PANEL 4 - BTU/HR FT**2 $ARR0460
0.00,08.91,0.05,16.24,0.10,23.28,0.15,29.74,0.20,35.34 $PANEL4
0.25,39.88,0.30,43.15,0.35,45.03,0.40,45.44,0.45,44.36 $PANEL4
0.50,41.84,0.55,37.49,0.60,32.94,0.65,26.93,0.70,20.18 $PANEL4
0.75,12.97,0.80,08.91,1.55,08.91,END $PANEL4

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17 $ INCIDENT HEAT FOR PANEL 5 - BTU/HR FT**2
0.00,32.37,0.05,35.41,0.10,38.32,0.15,41.00,0.20,43.32
0.25,45.20,0.30,46.56,0.35,47.34,0.40,47.51,0.45,47.06
0.50,46.02,0.55,44.41,0.60,42.33,0.65,39.83,0.70,37.04
0.75,34.05,0.80,35.82,0.85,43.35,0.90,32.37,1.45,32.37
1.50,40.76,1.55,32.37,END
18 $ INCIDENT HEAT FOR PANEL 6 - BTU/HR FT**2
0.00,49.71,0.05,54.38,0.10,58.86,0.15,62.97,0.20,66.54
0.25,69.42,0.30,71.50,0.35,72.70,0.40,72.96,0.45,72.28
0.50,70.67,0.55,68.22,0.60,65.01,0.65,61.18,0.70,56.88
0.75,52.29,0.80,56.54,0.85,71.47,0.90,49.71,1.45,49.71
1.50,66.34,1.55,49.71,END
19 $ INCIDENT HEAT FOR PANEL 7 - BTU/HR FT**2
0.00,56.74,0.05,62.08,0.10,67.19,0.15,71.88,0.20,75.95
0.25,79.25,0.30,81.62,0.35,82.99,0.40,83.29,0.45,82.50
0.50,80.67,0.55,77.87,0.60,74.21,0.65,69.84,0.70,64.93
0.75,59.69,0.80,64.60,0.85,81.75,0.90,56.74,1.45,56.74
1.50,75.86,1.55,56.74,END
20 $ INCIDENT HEAT FOR PANEL 8 - BTU/HR FT**2
0.00,31.81,0.05,34.80,0.10,37.66,0.15,40.29,0.20,42.57
0.25,44.42,0.30,45.75,0.35,46.52,0.40,46.68,0.45,46.25
0.50,45.22,0.55,43.65,0.60,41.60,0.65,39.15,0.70,36.40
0.75,33.46,0.80,35.13,0.85,42.39,0.90,31.81,1.45,31.81
1.50,39.90,1.55,31.81,END
21,SPACE,56,END
22,SPACE,81,END $ REYNOLDS NUMBER
23,SPACE,81,END
24 $RELATIVE ENTHALPY OF GLYCOL-WATER,BTU/LBM
-460.,0.0,-50.,131.0,-40.,137.12,-30.,143.36,-20.,149.73
-10.,156.22,0.0,162.83,10.,169.54,20.,176.37,30.,183.3
40.,190.33,50.,197.46,60.,204.69,70.,212.01,80.,219.43
90.,226.93,100.,234.51,110.,242.17,120.,249.9,130.,257.71
140.,265.58,150.,273.52,160.,281.52,170.,289.58,180.,297.7
190.,305.86,200.,314.08,230.,339.04,270.,373.04,310.,407.8
END
25,SPACE,48,END
26 $ DO LOOP INDICES - INITIAL VALUE
0.,1.,6.2,1.,END
27 $ DO LOOP INDICES - TEST VALUE
0.,1.,6.2,1.,END
28 $ DO LOOP INDICES - INCREMENT
0.,1.,6.2,1.,END
29,SPACE,10,END $ NOT USED
30,SPACE,10,END $ NOT USED
31,SPACE,10,END $ NOT USED
32,SPACE,10,END $ NOT USED
33,SPACE,10,END $ NOT USED
34,SPACE,10,END $ NOT USED
35 $ BYPASS OPTION - SYSTEM 1
0.,0.,3.1,0.,3.101,1.,6.2,1.,END
36 $ BYPASS OPTION - SYSTEM 2
0.,0.,6.2,0.,END
37 $ BYPASS OPTION - SYSTEM 3
0.,0.,6.2,0.,END
38 $ HEAT TRANSFER COEFFICIENT - AREA TERM
11,11,50.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.
120.,209.,243.,265.,289.,318.,345.,377.,0.,0.,0.,0.
130.,205.,238.,258.,281.,308.,333.,362.,404.,0.,0.,0.
140.,202.,234.,253.,275.,300.,323.,350.,387.,0.,0.,0.
150.,199.,230.,248.,269.,293.,315.,339.,374.,408.,0.,0.
160.,197.,227.,244.,264.,287.,307.,330.,363.,395.,0.,0.
170.,195.,224.,241.,260.,282.,301.,323.,353.,383.,417.,0.
180.,193.,221.,237.,256.,276.,295.,315.,344.,371.,404.,0.
190.,190.,218.,234.,251.,272.,289.,308.,335.,361.,391.,417.
$ARR0480
$PANEL5
$PANEL5
$PANEL5
$PANEL5
$PANEL5
$ARR0500
$PANEL6
$PANEL5
$PANEL5
$PANEL5
$PANEL6
$ARR0520
$PANEL7
$PANEL7
$PANEL7
$PANEL7
$PANEL7
$ARR0540
$PANEL8
$PANEL8
$PANEL8
$PANEL8
$PANEL8
$ARR0560
$ARR0570
$ARR0580
$ARR0600
$TVA0001
$TVA0002
$TVA0003
$TVA0004
$TVA0005
$TVA0006
$TVA0007
$TVA0008
$TVA0009
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200.,189.,216.,231.,249.,268.,285.,303.,329.,354.,381.,406.	\$TVA0010
210.,189.,216.,231.,248.,268.,284.,303.,329.,354.,381.,406.	\$TVA0011
220.,187.,214.,229.,245.,264.,280.,298.,323.,346.,372.,395.	\$TVA0012
11,11,55.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.	\$TVA0013
120.,223.,263.,287.,312.,342.,373.,409.,0.,0.,0.,0.	\$TVA0014
130.,220.,258.,280.,304.,332.,360.,393.,434.,0.,0.,0.,0.	\$TVA0015
140.,216.,254.,275.,297.,323.,349.,380.,417.,0.,0.,0.,0.	\$TVA0016
150.,213.,250.,270.,291.,316.,340.,369.,403.,438.,0.,0.,0.,0.	\$TVA0017
160.,211.,246.,265.,285.,309.,332.,359.,391.,423.,0.,0.,0.,0.	\$TVA0018
170.,208.,243.,262.,281.,304.,325.,351.,381.,411.,449.,0.	\$TVA0019
180.,206.,240.,258.,276.,298.,319.,343.,371.,399.,435.,0.	\$TVA0020
190.,203.,237.,254.,272.,293.,313.,335.,362.,388.,421.,452.	\$TVA0021
200.,202.,234.,251.,269.,289.,308.,330.,356.,381.,412.,441.	\$TVA0022
210.,202.,234.,251.,269.,289.,308.,330.,355.,380.,411.,440.	\$TVA0023
220.,200.,232.,248.,265.,285.,303.,324.,348.,372.,402.,429.	\$TVA0024
11,11,60.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.	\$TVA0025
120.,240.,285.,310.,334.,365.,398.,438.,0.,0.,0.,0.	\$TVA0026
130.,236.,279.,303.,325.,354.,384.,421.,462.,0.,0.,0.,0.	\$TVA0027
140.,233.,274.,296.,318.,345.,373.,407.,444.,0.,0.,0.,0.	\$TVA0028
150.,230.,270.,291.,311.,337.,363.,395.,429.,467.,0.,0.,0.,0.	\$TVA0029
160.,227.,266.,286.,306.,330.,355.,385.,417.,452.,0.,0.,0.,0.	\$TVA0030
170.,225.,263.,282.,301.,324.,348.,376.,407.,439.,478.,0.	\$TVA0031
180.,222.,259.,278.,296.,319.,341.,368.,396.,426.,463.,0.	\$TVA0032
190.,220.,256.,274.,292.,313.,335.,360.,387.,415.,449.,483.	\$TVA0033
200.,218.,253.,271.,288.,309.,330.,354.,380.,407.,439.,472.	\$TVA0034
210.,218.,253.,271.,288.,309.,330.,354.,380.,406.,439.,470.	\$TVA0035
220.,216.,252.,268.,285.,305.,325.,348.,372.,398.,429.,459.	\$TVA0036
11,11,65.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.	\$TVA0037
120.,256.,305.,331.,354.,385.,421.,462.,0.,0.,0.,0.	\$TVA0038
130.,252.,299.,324.,345.,374.,407.,445.,488.,0.,0.,0.,0.	\$TVA0039
140.,248.,294.,317.,338.,364.,395.,430.,470.,0.,0.,0.,0.	\$TVA0040
150.,245.,289.,311.,331.,356.,385.,418.,454.,494.,0.,0.,0.,0.	\$TVA0041
160.,242.,285.,307.,325.,349.,377.,408.,442.,477.,0.,0.,0.,0.	\$TVA0042
170.,240.,281.,302.,320.,343.,369.,399.,431.,465.,505.,0.	\$TVA0043
180.,237.,278.,298.,315.,337.,362.,390.,420.,452.,489.,0.	\$TVA0044
190.,234.,274.,294.,310.,331.,355.,382.,410.,440.,474.,511.	\$TVA0045
200.,233.,272.,291.,307.,327.,350.,376.,403.,432.,464.,499.	\$TVA0046
210.,232.,272.,291.,306.,327.,350.,376.,403.,431.,464.,498.	\$TVA0047
220.,231.,269.,287.,303.,323.,345.,369.,395.,423.,454.,486.	\$TVA0048
11,11,70.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.	\$TVA0049
120.,266.,322.,350.,373.,403.,441.,484.,0.,0.,0.,0.	\$TVA0050
130.,262.,316.,343.,364.,392.,427.,467.,512.,0.,0.,0.,0.	\$TVA0051
140.,258.,310.,336.,356.,382.,415.,452.,493.,0.,0.,0.,0.	\$TVA0052
150.,255.,306.,330.,349.,374.,405.,439.,478.,521.,0.,0.,0.,0.	\$TVA0053
160.,252.,301.,325.,343.,367.,396.,428.,465.,505.,0.,0.,0.,0.	\$TVA0054
170.,249.,298.,320.,337.,360.,389.,419.,453.,491.,529.,0.	\$TVA0055
180.,247.,294.,316.,332.,354.,381.,410.,442.,477.,513.,0.	\$TVA0056
190.,244.,290.,311.,327.,348.,374.,401.,432.,465.,498.,536.	\$TVA0057
200.,242.,287.,308.,324.,344.,369.,395.,425.,456.,488.,524.	\$TVA0058
210.,242.,287.,308.,323.,344.,368.,395.,424.,456.,487.,523.	\$TVA0059
220.,240.,284.,305.,320.,339.,363.,389.,417.,447.,477.,510.	\$TVA0060
11,11,75.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.	\$TVA0061
120.,266.,334.,366.,389.,420.,460.,504.,0.,0.,0.,0.	\$TVA0062
130.,262.,328.,358.,379.,408.,446.,486.,535.,0.,0.,0.,0.	\$TVA0063
140.,258.,322.,351.,371.,398.,433.,470.,515.,0.,0.,0.,0.	\$TVA0064
150.,255.,317.,345.,364.,390.,423.,458.,499.,546.,0.,0.,0.,0.	\$TVA0065
160.,252.,313.,340.,358.,383.,414.,447.,486.,529.,0.,0.,0.,0.	\$TVA0066
170.,250.,309.,335.,353.,376.,406.,437.,474.,515.,552.,0.	\$TVA0067
180.,247.,305.,330.,347.,370.,399.,428.,463.,501.,536.,0.	\$TVA0068
190.,245.,301.,326.,342.,364.,391.,419.,452.,488.,520.,559.	\$TVA0069
200.,243.,299.,322.,338.,359.,386.,413.,445.,479.,510.,546.	\$TVA0070
210.,243.,299.,322.,338.,359.,386.,413.,445.,479.,509.,546.	\$TVA0071
220.,241.,296.,319.,334.,354.,380.,406.,437.,469.,498.,533.	\$TVA0072



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11,11,80.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180. $TVA0073
120.,254.,337.,376.,401.,434.,477.,522.,0.,0.,0.,0. $TVA0074
130.,250.,333.,368.,392.,423.,463.,504.,555.,0.,0.,0. $TVA0075
140.,247.,327.,361.,384.,413.,450.,488.,536.,0.,0.,0. $TVA0076
150.,244.,322.,355.,377.,404.,439.,475.,519.,568.,0.,0. $TVA0077
160.,242.,318.,350.,370.,397.,430.,464.,506.,552.,0.,0. $TVA0078
170.,239.,314.,345.,365.,390.,422.,455.,494.,537.,574.,0. $TVA0079
180.,237.,310.,340.,359.,384.,415.,445.,483.,523.,557.,0. $TVA0080
190.,235.,307.,336.,354.,378.,407.,436.,472.,510.,542.,581. $TVA0081
200.,233.,304.,333.,350.,373.,402.,430.,464.,501.,531.,568. $TVA0082
210.,233.,304.,332.,350.,373.,401.,430.,464.,500.,530.,567. $TVA0083
220.,231.,301.,329.,346.,368.,396.,423.,456.,491.,519.,554. $TVA0084
11,11,85.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180. $TVA0085
120.,230.,335.,380.,410.,447.,473.,540.,0.,0.,0.,0. $TVA0086
130.,227.,329.,372.,401.,436.,478.,521.,574.,0.,0.,0. $TVA0087
140.,224.,324.,365.,393.,426.,465.,506.,555.,0.,0.,0. $TVA0088
150.,222.,319.,359.,385.,417.,454.,492.,538.,589.,0.,0. $TVA0089
160.,220.,315.,354.,379.,410.,445.,481.,524.,572.,0.,0. $TVA0090
170.,218.,312.,350.,374.,403.,437.,471.,512.,557.,596.,0. $TVA0091
180.,216.,308.,345.,369.,397.,429.,462.,501.,543.,579.,0. $TVA0092
190.,215.,305.,341.,363.,390.,422.,453.,490.,529.,563.,603. $TVA0093
200.,213.,302.,337.,359.,386.,416.,447.,482.,520.,552.,590. $TVA0094
210.,213.,302.,337.,359.,385.,416.,446.,482.,519.,552.,589. $TVA0095
220.,212.,299.,334.,355.,381.,410.,439.,473.,510.,540.,580. $TVA0096
11,11,90.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180. $TVA0097
120.,199.,322.,377.,414.,459.,507.,558.,0.,0.,0.,0. $TVA0098
130.,197.,317.,370.,405.,447.,492.,539.,592.,0.,0.,0. $TVA0099
140.,194.,312.,363.,397.,437.,479.,523.,572.,0.,0.,0. $TVA0100
150.,193.,308.,358.,390.,428.,468.,510.,556.,606.,0.,0. $TVA0101
160.,191.,305.,353.,384.,421.,459.,499.,542.,589.,0.,0. $TVA0102
170.,190.,301.,348.,379.,414.,451.,489.,530.,574.,618.,0. $TVA0103
180.,189.,298.,344.,374.,408.,443.,479.,518.,560.,601.,0. $TVA0104
190.,187.,295.,340.,369.,401.,435.,470.,507.,546.,585.,626. $TVA0105
200.,186.,293.,337.,365.,397.,430.,463.,499.,537.,574.,613. $TVA0106
210.,186.,293.,336.,364.,397.,430.,462.,499.,536.,574.,612. $TVA0107
220.,185.,290.,333.,361.,392.,424.,456.,490.,527.,562.,598. $TVA0108
END

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39 $ SPECIFIC VOLUME OF STEAM - FT**3/LBM
130.00,157.34,132.00,149.66,134.00,142.42,136.00,135.58
138.00,129.12,140.00,123.01,142.00,117.23,144.00,111.77
146.00,106.60,148.00,101.71,150.00, 97.07,152.00, 92.68
154.00, 88.52,156.00, 84.58,158.00, 80.84,160.00, 77.29
162.00, 73.92,164.00, 70.73,166.00, 67.69,168.00, 64.80
170.00, 62.06,172.00, 59.45,174.00, 56.97,176.00, 54.61
178.00, 52.37,180.00, 50.23,182.00, 48.19,184.00, 46.25
186.00, 44.40,188.00, 42.64,190.00, 40.96,192.00, 39.36
194.00, 37.83,196.00, 36.37,198.00, 34.97,200.00, 33.64
202.00, 32.37,204.00, 31.15,206.00, 29.99,208.00, 28.88,END

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40 $ SATURATION PRESSURE OF STEAM - PSIA
130.00, 2.22,132.00, 2.34,134.00, 2.47,136.00, 2.60
138.00, 2.74,140.00, 2.89,142.00, 3.04,144.00, 3.20
146.00, 3.36,148.00, 3.54,150.00, 3.72,152.00, 3.91
154.00, 4.10,156.00, 4.31,158.00, 4.52,160.00, 4.74
162.00, 4.97,164.00, 5.21,166.00, 5.46,168.00, 5.72
170.00, 5.99,172.00, 6.72,174.00, 6.56,176.00, 6.87
178.00, 7.18,180.00, 7.51,182.00, 7.85,184.00, 8.20
186.00, 8.57,188.00, 8.95,190.00, 9.34,192.00, 9.75
194.00, 10.17,196.00, 10.61,198.00, 11.06,200.00, 11.53
202.00, 12.01,204.00, 12.51,206.00, 13.03,208.00, 13.57,END

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41 $ CURRENT - AMPS - SYSTEM 1

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0.,30.,3.1,30.,3.101,25.,6.2,25.,END

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42 $ CURRENT - AMPS - SYSTEM 2

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0.,0.,6.2,0.,END

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43      $ CURRENT - AMPS - SYSTEM 3
0.,0.,6.2,0.,END
44      $ PARTIAL PRESSURE OF WATER IN STACK - PSIA
      8, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90
350.0, 27.0, 15.0, 8.0, 3.7, 1.6, 0.0, 0.0, 0.0
390.0, 36.0, 21.0, 11.4, 5.6, 2.4, 1.0, 0.0, 0.0
400.0, 47.0, 29.0, 16.0, 8.0, 3.4, 1.4, 0.0, 0.0
420.0, 61.0, 38.0, 21.4, 10.8, 4.8, 1.9, 0.0, 0.0
440.0, 79.0, 51.0, 29.0, 14.6, 6.6, 2.7, 1.0, 0.0
460.0, 102.0, 66.0, 38.0, 19.0, 8.9, 3.6, 1.3, 0.0
480.0, 128.0, 86.0, 50.0, 25.0, 11.9, 4.8, 1.7, 0.0
500.0, 160.0, 104.0, 65.0, 32.5, 15.6, 6.3, 2.2, 0.0
520.0, 200.0, 134.0, 83.0, 42.0, 20.6, 8.4, 3.0, 1.2
540.0, 250.0, 170.0, 104.0, 55.0, 27.5, 11.3, 4.2, 1.6
560.0, 310.0, 210.0, 130.0, 70.0, 36.0, 15.0, 5.9, 2.1
580.0, 380.0, 260.0, 160.0, 89.0, 46.0, 20.0, 8.0, 2.8
600.0, 470.0, 320.0, 195.0, 113.0, 60.0, 27.0, 10.7, 3.7,END
45      $ ENTHALPY OF SUPERHEATED STEAM - BTU/LBM
      5, 126.08, 152.97, 170.06, 182.86, 193.21
200.0, 1150.0, 1149.2, 1148.3, 1147.5, 1146.6
220.0, 1159.1, 1158.5, 1157.7, 1157.0, 1156.2
240.0, 1168.2, 1167.6, 1167.0, 1166.3, 1165.7
260.0, 1177.3, 1176.8, 1176.3, 1175.7, 1175.1
280.0, 1186.5, 1186.0, 1185.5, 1185.0, 1184.5
300.0, 1195.6, 1195.2, 1194.7, 1194.3, 1193.9
320.0, 1204.8, 1204.4, 1204.0, 1203.6, 1203.2
340.0, 1213.9, 1213.6, 1213.2, 1212.9, 1212.5
360.0, 1223.1, 1222.8, 1222.5, 1222.2, 1221.9
380.0, 1232.3, 1232.1, 1231.8, 1231.5, 1231.2
400.0, 1241.6, 1241.3, 1241.1, 1240.8, 1240.6,END
46,SPACE,1,END
47,SPACE,30,END
48,SPACE,30,END
49,SPACE,60,END      $ENTHALPY GLYCOL-WATER VS TEMP
50,SPACE,199,END      $SAVED TIME STEPS
51,SPACE,20,END      $RAD OUTLET TEMPS
52,SPACE,20,END
53,SPACE,20,END
54,SPACE,200,END      $SECONDARY REGEN COLD INLET TEMPS
55,SPACE,200,END
56,SPACE,200,END
57,SPACE,200,END      $SECONDARY BYPASS VALVE POSITION
58,SPACE,200,END
59,SPACE,200,END
60,SPACE,40,END      $GLYCOL OUTLET TEMPS FROM CONDENSER
61,SPACE,40,END
62,SPACE,40,END
63,SPACE,200,END      $SECONDARY REGEN HOT INLET TEMPS
64,SPACE,200,END
65,SPACE,200,END
66,SPACE,200,END      $SECONDARY REGEN GAINS, SYS 1
67,SPACE,200,END
68,SPACE,200,END
69,SPACE,200,END
70,SPACE,200,END      $SECONDARY REGEN GAINS, SYS 2
71,SPACE,200,END
72,SPACE,200,END
73,SPACE,200,END
74,SPACE,200,END      $SECONDARY REGEN GAINS, SYS 3
75,SPACE,200,END
76,SPACE,200,END
77,SPACE,200,END
78,SPACE,200,END      $SECONDARY REGEN COLD SIDE DELAYS
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79,SPACE,200,END
80,SPACE,200,END
81,SPACE,20,END      $SECONDARY REGEN HOT OUTLET TEMPS
82,SPACE,20,END
83,SPACE,20,END
84      $ SYSTEM FLOW RATE VERSES RAD PRESS DRDP
      0.,88.0,  5.,84.7, 10.,81.5, 15.,78.2, 20.,75.0, 25.,71.7
      30.,68.4, 35.,65.2, 40.,61.9, 45.,58.7, 50.,55.4, 55.,52.2
      60.,48.9, 65.,45.6, 70.,42.4, 75.,39.1, 80.,35.9, 85.,32.6
      90.,29.3, 95.,26.1,100.,22.8,105.,19.6,110.,16.3,115.,13.0
      120., 9.8,125., 6.5,130., 3.3,END
END

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MAIN PROGRAM LISTING

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      BCD 3EXECUTION
      COMMON/ALPHA/ WH2026(3)
      COMMON/BRAVO/QCOND(3), DMASS(3), WTH230(3)
      COMMON/CHARLE/J,M,N
      COMMON/DELTA/ INDEX1
      COMMON/ECHO/ IPOINT
      DIMENSION X(1000)
      DIMENSION XK(1)
      EQUIVALENCE (XK(1),K(1))
      NDIM=1000
      NTH=0

      SCLDEP(A4,K1) $SCALE VISCOSITY
      SPLIT(K2,A1+1,A5+1,A6+1) $SEPARATE DENSITY FROM TEMP
      ARYINV(K2,A6+1) $INVERT DENSITY
      JOIN(K2,A5+1,A6+1,A1+1) $ INVERSE DENSITY VS TEMP
      SPLIT(K2,A2+1,A5+1,A6+1) $SEPARATE CONDUCTIVITY FROM TEMP
      SPLIT(K2,A3+1,A5+1,A7+1) $SEPARATE SPECIFIC HEAT FROM TEMP
      DIVARY(K2,A6+1,A7+1,A7+1)$CONDUCTIVITY / SPECIFIC HEAT
      JOIN(K2,A5+1,A7+1,A21+1) $CONDUCTIVITY/SPECIFIC HEAT VS TEMP
      SPLIT(K2,A4+1,A5+1,A6+1) $SEPARATE VISCOSITY FROM TEMP
      ARYINV(K2,A6+1) $ INVERT VISCOSITY
      JOIN(K2,A5+1,A6+1,A4+1) $INVERSE VISCOSITY VS TEMP
      SPLIT(K916,A24+1,A47+1,A49+1) $SEPARATE TEMP FROM ENTHALPY
      JOIN(K916,A48+1,A47+1,A49+1) $ENTHALPY VS TEMP

      REM
      REM DATA ARRAY IS NOW IN PROPER FORM FOR PROGRAM USAGE
      REM
      REM THE FOLLOWING INITIALIZES THE ENTIRE SOLID TEMPERATURE
      REM NETWORK TO COMPENSATE FOR VARYING INITIAL CONDITIONS. THE
      REM TEMPERATURE VALUE IS INPUT AS CONSTANT NUMBER K598.
      STFSQS(K598,K599,T701)

      IPOINT = 1
      INDEX1 = 0
      J = XK(398) + 0.0001
      M = XK(399) + 0.0001
      N = XK(400) + 0.0001
      DO 100 I = J, M, N
      WH2026(I) = (XK(I + 325)/XK(I + 328)) - XK(I + 325)
100  CONTINUE
      REM*****BEGIN INITIALIZATION OF SECONDARY LOOP COMPONENTS*****
      REM FIRST INITIALIZE CONSTANT LOCATIONS
      DO 110 I=J,M,N
      REM INITIALIZE SEC BP VLV STAT POS TO INITIAL DYNAMIC VALUE
      XK(I+456)=XK(I+374)
      XK(I+365)=XK(I+331)
      RTEST=XK(I+331)
      D1DEG1(RTEST,A10,TTEST)
      XK(I+374)=TTEST
      XK(I+381)=(1./XK(I+51))
      REM SET REG HOT INLET = COND GLY OUT
110  XK(I+391)=XK(I+388)
      REM SET REG COLD INLET = RAD OUTLET
      STFSQS(T618,1,K890)
      STFSQS(T636,1,K891)
      STFSQS(T654,1,K892)
      REM TIME STEP
      STFSQS(.002,K913,A50+1)
      REM NOW SOLVE SYSTEM IN STEADY STATE
      DO 300 I=J,M,N
      IF(I-2) 120,130,140

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120      D3DEGI(K890,K896,K6,A38,RTEST)
          D1DEGI(K890,A3,STEST)
          D1DEGI(K896,A3,TTEST)
GO TO 145
130      D3DEGI(K891,K897,K7,A38,RTEST)
          D1DEGI(K891,A3,STEST)
          D1DEGI(K897,A3,TTEST)
GO TO 145
140      D3DEGI(K892,K898,K8,A38,RTEST)
          D1DEGI(K892,A3,STEST)
          D1DEGI(K898,A3,TTEST)
145 FLOWC=(1.-XK(I+374))*XK(I+5)
      UA=RTEST
      CPC=STEST
      CPH=TTEST
      CC=FLOWC*CPC
      CH=XK(I+5)*CPH
      BETA=CC/CH
      RNTU=UA/CC
      ET=EXP(-RNTU*(1.-BETA))
      EFF=(1.-ET)/(1.-BETA*ET)
      RTEST=1.-EFF
      STEST=EFF
      TTEST=EFF*BETA
      UTEST=1.-TTEST
      XK(I+377)=RTEST*XK(I+385) + STEST*XK(I+391)
      XK(I+394)=TTEST*XK(I+385) + UTEST*XK(I+391)
      IF(XK(I+374).GT.XK(381)) GO TO 147
      VTEST=(1./FLOWC)*67.*XK(361)
      GO TO 150
147 VTEST=1000.
150 CONTINUE
      IF(I-2) 155,160,165
155      STFSQS(RTEST,K912,A66+1)
          STFSQS(STEST,K912,A67+1)
          STFSQS(TTEST,K912,A68+1)
          STFSQS(UTEST,K912,A69+1)
          STFSQS(VTEST,K912,A78+1)
GO TO 170
160      STFSQS(RTEST,K912,A70+1)
          STFSQS(STEST,K912,A71+1)
          STFSQS(TTEST,K912,A72+1)
          STFSQS(UTEST,K912,A73+1)
          STFSQS(VTEST,K912,A79+1)
GO TO 170
165      STFSQS(RTEST,K912,A74+1)
          STFSQS(STEST,K912,A75+1)
          STFSQS(TTEST,K912,A76+1)
          STFSQS(UTEST,K912,A77+1)
          STFSQS(VTEST,K912,A80+1)
170 CONTINUE
      REM INITIALIZE REMAINDER OF CONSTANTS
      REM COND GLY IN = REG COLD OUT
      XK(I+403)=XK(I+377)
      REM INITIALIZE REMAINING ARRAYS
      IF(I-2) 200,210,220
200      STFSQS(K890,K914,A51+1)  $RAD OUT
          STFSQS(K890,K912,A54+1)  $REG COLD IN
          STFSQS(K879,K912,A57+1)  $BP VLV FRAC
          STFSQS(K893,K915,A60+1)  $COND GLY OUT
          STFSQS(K893,K912,A63+1)  $REG HOT IN
          STFSQS(K899,K914,A81+1)  $REG HOT OUT
GO TO 230

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210      STFSQS(K891,K914,A52+1)
        STFSQS(K891,K912,A55+1)
        STFSQS(K880,K912,A58+1)
        STFSQS(K894,K915,A61+1)
        STFSQS(K894,K912,A64+1)
        STFSQS(K900,K914,A82+1)
GO TO 230
220      STFSQS(K892,K914,A53+1)
        STFSQS(K892,K912,A56+1)
        STFSQS(K881,K912,A59+1)
        STFSQS(K895,K915,A62+1)
        STFSQS(K895,K912,A65+1)
        STFSQS(K901,K914,A83+1)
230 CONTINUE
      REM END OF INITIALIZATION LOOP*****
300 CONTINUE
      VARBL2 $ ANALYZE PRESSURE NETWORK AND OBTAIN FLOW RATES
      CNFRWD $ PERFORM TRANSIENT ANALYSIS
      END
      BCD 3VARIABLES 1
      COMMON/ALPHA/ WH2026(3)
      COMMON/BRAVO/QCOND(3),DMASS(3),WTH230(3)
      COMMON/CHARLE/J,M,N
      COMMON/FOXTROT/ PCKOH(3)
      DIMENSION SVOL11(3),WH202P(3),PRES31(3),SVOL31(3),
1          WH2030(3),SVOL21(3),DSPVOL(3),SFCH2(3),SFCO2(3),
2          QGENAT(3),QH2(3),QO2(3),QSELECT(3),PARPH2(3),SVOL32(3),
3          WOTCP2(3),QRS(3),QSTOR0(3),SVOL12(3),QSM(3),
4          QREACT(3),QH2D(3),QOUT(3),QIN(3),DELTAQ(3),
5          TSKIN1(3),DTEMP(3),TSKIN2(3),WH2020(3),DIFF(3),
6          WOTCP1(3),WH2025(3)
      DIMENSION XK(1)
      EQUIVALENCE (XK(1),K(1))
      REM INTERPOLATE DO LOOP INDEX ARRAYS
          D1DEG1(TIMEN,A26,K902) $ J
          D1DEG1(TIMEN,A27,K903) $ M
          D1DEG1(TIMEN,A28,K904) $ N
      REM CHANGE INDICES FROM FLOATING POINT TO INTEGER
          FIX(K902,K26) $ J
          FIX(K903,K28) $ M
          FIX(K904,K32) $ N
      J=K(26)
      M=K(28)
      N=K(32)
      DO 667 I = 1,3
667      XK(I + 469) = XK(I + 5)
      DO 668 I = 1, 3
668      XK(I + 5) = 0.0001
      DO 669 I = J, M, N
669      XK(I + 5) = XK(I + 469)
          D1DEG1(TIMEN,A41,K854) $ SYSTEM 1
          D1DEG1(TIMEN,A42,K855) $ SYSTEM 2
          D1DEG1(TIMEN,A43,K856) $ SYSTEM 3
      DO 500 I = J, M, N
      DT = 10.
      IF (I - 2) 1, 2, 3
1          D1DEG2(K836, A39, K920)
          D1DEG2(K836, A40, K932)
      GO TO 4
2          D1DEG2(K837, A39, K921)
          D1DEG2(K837, A40, K933)
      GO TO 4
3          D1DEG2(K838,A39,K922)
          D1DEG2(K838, A40, K934)

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4  CONTINUE
   SVOL11(I) = XK(I+415)
   ORATE = 0.05
   IOLD = 1
   DO 90 JJ = 1, 100
     WH202P(I) = XK(I+349)*XK(I+349)*DTIMEU
     WH2025(I) = WH2026(I) + XK(I + 345)*WH202P(I)
     PCKOH(I) = XK(I+325)/(XK(I+325) + WH2025(I))
     XK(I+424) = PCKOH(I)
     IF (I - 2) 21, 22, 23
21    D2DEG2(K929, K847, A44, K926)
     GO TO 24
22    D2DEG2(K930, K848, A44, K927)
     GO TO 24
23    D2DEG2(K931, K849, A44, K928)
24  CONTINUE
     PRES31(I) = XK(I+421)
     SVOL31(I) = (XK(335)*(XK(I+342)+460.))/(PRES31(I)*144.)
     DMASS(I) = (1.0-XK(I+345))*WH202P(I)
     WH2030(I) = XK(I+336)*DTIMEU/SVOL31(I)
     WH2020(I) = WH2030(I) - DMASS(I)
     SVOL21(I) = XK(I+336)*DTIMEU/WH2020(I)
     DSPVOL(I) = SVOL11(I) - SVOL21(I)
     IF (ABS(DSPVOL(I)) - XK(353)) 100, 100, 35
35    IF (DSPVOL(I)) 45, 100, 50
45    IMULT = 1
     INEW = IOLD
     IOLD = -1
     GO TO 60
50    IMULT = -1
     INEW = IOLD
     IOLD = 1
60    XK(I + 345) = XK(I + 345) + ORATE*IMULT
     IF (INEW - IOLD) 70, 90, 70
70    ORATE = ORATE/2.0
90    CONTINUE
     WRITE (6, 95)
95    FORMAT (79H ITERATIVE SCHEME DID NOT FIND A SOLUTION WITHIN SPECIFIED
100   NUMBER OF ITERATIONS)
     CONTINUE
     WH2026(I) = WH2025(I)
     XK(I+353) = 5.57344 - 1.277138*XK(I+349)
1  +2.654927E-3*XK(I+349)**2 - 1.335417E-5*XK(I+349)**3
2  +9.694669E-2*XK(I+342) + 4.686233E-2*XK(I+349)*XK(I+42)
3  - 3.573639E-7*XK(I+349)**2*XK(I+342) - 1.525995E-5*XK(I+342)**2
4  -4.889387E-6*XK(I+349)*XK(I+342)**2 - 1.292758E-7*XK(I+342)**3
     XK(I + 353) = XK(I + 353) - 24.1*(.75 - PCKOH(I))
     XK(I + 412) = XK(I + 349)*XK(I + 353)
     SFCH2(I) = 8.292E-5*31.*XK(I+349)
     SFCO2(I) = 7.94*SFCH2(I)
     QGENAT(I) = 51600.*SFCH2(I)
     QH2(I) = SFCH2(I)*3.43*(XK(I + 342) - XK(I + 463))
     QO2(I) = SFCO2(I)*0.219*(XK(I + 342) - XK(I + 466))
     QELECT(I) = 3.41276*XK(I+349)*XK(I+353)
     PARPH2(I) = 60. - PRES31(I)
     SVOL32(I) = (XK(336)*(XK(I + 342) + 460.))/(PARPH2(I)*144.)
     WDTCP1(I) = (XK(I+336)/SVOL31(I))*0.445
     WDTCP2(I) = (XK(I+336)/SVOL32(I))*3.48
     QRS(I) = (WDTCP1(I)+WDTCP2(I))*XK(I+342)-XK(I+339)
     QSM(I) = 3.25*XK(I + 342) - 1.6*XK(I + 439) - 882.
     QSTORD(I) = QGENAT(I) - QH2(I) - QO2(I) - QELECT(I) - QRS(I) -
1  QSM(I)
     XK(I+342) = XK(I+342) + (QSTORD(I)*DTIMEU)/XK(358)

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SVOL12(I) = (XK(336)*(XK(I+331)+460.))/(PARPH2(I)*144.)      F
WTH230(I) = (XK(I+336)/SVOL12(I)-XK(I+349)*XK(443))*DTIMEU    F
QREACT(I) = (XK(445)*DMASS(I))/DTIMEU +                        F
1      XK(444)*(XK(I + 349)*XK(349) - DMASS(I)/DTIMEU)        F
QH2O(I) = (DMASS(I)*(XK(I + 331) - XK(I + 439))*1.0)/DTIMEU    F
CONST1 = 3.44*WTH230(I)/DTIMEU+XK(I+336)/XK(I+415)*1.0        F
1      + DMASS(I)*1.0/DTIMEU                                    F
CONST2 = 1160.*DMASS(I)/DTIMEU                                  F
CONST3 = ((XK(I+336)/SVOL12(I))*3.44+(XK(I+336)/SVOL11(I))*1.0)/ F
1      ((WTH230(I)/DTIMEU)*3.44+(WH2O30(I)/DTIMEU)*1.0)        F
CONST4 = -1.2*XK(I + 342) + 882.                                F
150  XK(I + 371) = XK(I + 342) - (XK(I + 339) - XK(I + 331))*CONST3 F
QCOND(I) = (XK(I + 371) - XK(I + 331))*CONST1 + CONST2        F
QOUT(I) = QREACT(I)                                            F
QIN(I) = QCOND(I) + QH2O(I) + QELECT(I) + QSM(I) + QSTORD(I)  F
DELTAQ(I) = QOUT(I) - QIN(I)                                    F
IF (ABS(DELTAQ(I)) - XK(449)) 180, 180, 160                    F
160  IF (ABS(CONST4 - XK(I + 339)) - XK(450)) 180, 180, 165    F
165  IF (ABS(CONST4 - CONST5) - ABS(CONST4 - XK(I + 339))) 168,168,170 F
168  DT = -DT/2.                                                F
170  CONST5 = XK(I + 339)                                        F
      XK(I + 339) = XK(I + 339) + DT                            F
      GO TO 150                                                  F
180  CONTINUE                                                  F
      XK(I+450) = DMASS(I)/DTIMEU                                F
      XK(I+453) = XK(I+345)*100.                                F
500  CONTINUE                                                  F
      REM INTERPOLATE BYPASS OPTION ARRAY
      D1DEG1(TIMEN,A35,K905) $ SYSTEM 1
      D1DFG1(TIMEN,A36,K906) $ SYSTEM 2
      D1DEG1(TIMEN,A37,K907) $ SYSTEM 3
      REM CHANGE BYPASS FROM FLOATING POINT TO INTEGER
      FIX(K905,K9) $ SYSTEM 1
      FIX(K906,K10) $ SYSTEM 2
      FIX(K907,K11) $ SYSTEM 3
      REM INTERPOLATE HEAT FLUX ARRAYS
      RTEST = TIMEM
      IF(TIMEN.GE.1.55) RTEST = TIMEM - 1.55*FLOAT(IFIX(TIMEM/1.55)) F
      D11CYL(K600,RTEST,A13,K12) $ PANEL 1
      D11CYL(K600,RTEST,A14,K13) $ PANEL 2
      D11CYL(K600,RTEST,A15,K14) $ PANEL 3
      D11CYL(K600,RTEST,A16,K15) $ PANEL 4
      D11CYL(K600,RTEST,A17,K16) $ PANEL 5
      D11CYL(K600,RTEST,A18,K17) $ PANEL 6
      D11CYL(K600,RTEST,A19,K18) $ PANEL 7
      D11CYL(K600,RTEST,A20,K19) $ PANEL 8
      REM APPLY INCIDENT HEAT
      REM
      ARYMPY(K20,A12+1,K12,Q701) $PANEL 1
      ARYMPY(K20,A12+1,K13,Q725) $PANEL 2
      ARYMPY(K20,A12+1,K14,Q749) $PANEL 3
      ARYMPY(K20,A12+1,K15,Q773) $PANEL 4
      ARYMPY(K20,A12+1,K16,Q797) $PANEL 5
      ARYMPY(K20,A12+1,K17,Q821) $PANEL 6
      ARYMPY(K20,A12+1,K18,Q845) $PANEL 7
      ARYMPY(K20,A12+1,K19,Q869) $PANEL 8
      REM
      REM BUILD A TEMPERATURE ARRAY TO EVALUATE THERMAL FLUID FLOW COND
      REM
      BLDARY(A9+1,T601,T602,T603,T604,T605,T606,T607,T608,T609
      T610,T611,T612,T613,T614,T615,T616,T617,T611
      T619,T620,T621,T622,T623,T624,T625,T626,T627)
      BLDARY(A9+28,T628,T629,T630,T631,T632,T633,T634,T635,T629

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1637,1638,1639,1640,1641,1642,1643,1644,1645
1646,1647,1648,1649,1650,1651,1652,1653,1647)

REM EVALUATE CONVECTION CONDUCTORS

REM

REM

REM EVALUATE GR NUMBER

DIDIMI(K22,A9+2,A21,K805,G1001) \$SYSTEM 1

DIDIMI(K22,A9+20,A21,K805,G1017) \$SYSTEM 2

DIDIMI(K22,A9+38,A21,K805,G1033) \$SYSTEM 3

ARMMPY(K22,G1001,K821,G1001) \$SYSTEM 1

ARMMPY(K22,G1017,K822,G1017) \$SYSTEM 2

ARMMPY(K22,G1033,K823,G1033) \$SYSTEM 3

DO 40 I=12,59

40 G(I)=46.1235*(.19533/(G(I)+.015*(G(I)**.33333333)))

DIDIMI(K22,A9+2,A2,G1001,G1001) \$SYSTEM 1

DIDIMI(K22,A9+20,A2,G1017,G1017) \$SYSTEM 2

DIDIMI(K22,A9+38,A2,G1033,G1033) \$SYSTEM 3

REM

REM EVALUATE FLUID FLOW CONDUCTORS - G = M*C

REM

REM

DIDIMI(K24,A9+1,A3,K6,G601) \$SYSTEM 1

DIDIMI(K24,A9+19,A3,K7,G619) \$SYSTEM 2

DIDIMI(K24,A9+37,A3,K8,G637) \$SYSTEM 3

IF(K(9)) 10,10,11

10 G(158) = 0.

11 CONTINUE

STFSQS(K594,K595,G611)

12 IF(K(10)) 13,13,14

13 G(176) = 0.

GO TO 15

14 CONTINUE

STFSQS(K594,K595,G629)

15 IF(K(11)) 16,16,17

16 G(194) = 0.

GO TO 18

17 CONTINUE

STFSQS(K594,K595,G647)

18 CONTINUE

END

BCD VARIABLES 2

COMMON/CHARLE/ J, M, N

COMMON/BRAND/COND(3),DMASS(3),MTW230(3)

COMMON/DELTA/ INDEX

DIMENSION XK(1)

EQUIVALENCE (XK(1),K(1))

REM BUILD A TEMPERATURE ARRAY FOR USE IN COMPUTING CONDUCTANCES

BLDARY(A8+1,T601,T602,T603,T604,T605,T606,T607

T607,T608,T609,T609,T610,T611,T612,T613

T613,T614,T615,T615,T616,T617,T617,T618,T611)

BLDARY(A8+28,T619,T620,T621,T621,T622,T623,T624,T625

T625,T626,T627,T627,T628,T629,T629,T630,T631

T631,T632,T633,T633,T634,T635,T635,T636,T629)

BLDARY(A8+55,T637,T638,T639,T639,T640,T641,T641,T643

T643,T644,T645,T645,T646,T647,T647,T648,T649

T649,T650,T651,T651,T642,T653,T653,T654,T647)

REM COMPUTE REYNOLDS NUMBERS

DIDIMI(A8,A8+1,A4,K601,A22+1) \$ (4/(P*VIS))

ARMMPY(K5,A22+1,K6,A22+1) \$ RE FOR SYSTEM 1

ARMMPY(K5,A22+28,K7,A22+28) \$ RE FOR SYSTEM 2

ARMMPY(K5,A22+55,K8,A22+55) \$ RE FOR SYSTEM 3

REM COMPUTE (R*MP*LI)/((A**3)*(DENSITY))

DIDIMI(A8,A8+1,A1,K501,G501)



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REM COMPUTE (K-FACTOR)/(2*DENSITY*(A**2))
  DIDIMI(A8,A8+1,A1,K701,A23+1)
  DIVARY(A23,G501,A22+1,G501)
  ADDARY(A23,A23+1,G501,G501)
REM - ALL CONSTANTS FOR PRESSURE DROP HAVE BEEN COMPUTED -- SUM
REM FOR RESPECTIVE SYSTEMS AND SOLVE FOR DELP
REM
REM IN THE FOLLOWING SYSTEMS COMPRESSIONS A FLAG HAS BEEN SET
REM TO INDICATE FLOW DIRECTION THROUGH THE BYPASS VALVES -- THE
REM SYSTEM CONDUCTANCE IS CALCULATED ACCORDINGLY
REM   FLAG FOR SYSTEM 1 = K9 (O-RADIATOR , 1-BYPASS)
REM   FLAG FOR SYSTEM 2 = K10(O-RADIATOR , 1-BYPASS)
REM   FLAG FOR SYSTEM 3 = K11(O-RADIATOR , 1-BYPASS)
REM
REM COMPRESS PRESSURE NETWORK FOR SYSTEM 1
REM
  SUMMARY(K3,G501,K582)
  SUMMARY(K4,G516,K583)
IF(K(9).EQ.0) K(117)=K(116)
IF(K(9).EQ.1)XK(117)=G(86)
  ADD(K582,K584,G526,K585)
REM
REM COMPRESS PRESSURE NETWORK FOR SYSTEM 2
REM
  SUMMARY(K3,G528,K586)
  SUMMARY(K4,G543,K587)
IF(K(10).EQ.0) K(121)=K(120)
IF(K(10).EQ.1)XK(121)=G(113)
  ADD(K586,K588,G553,K589)
REM
REM COMPRESS PRESSURE NETWORK FOR SYSTEM 3
REM
  SUMMARY(K3,G555,K590)
  SUMMARY(K4,G570,K591)
IF(K(11).EQ.0) K(125)=K(124)
IF(K(11).EQ.1)XK(125)=G(140)
  ADD(K590,K592,G580,K593)
  SCALE(K25,K585,K585,K589,K589,K593,K593)
  ARINDV(3,K6,1.,K821) $INVERT FLOW RATES
REM SAVE TIME STEP
REM FIRST TIME STEP, DTIMEU=0., SO DON'T STORE IT
IF(DTIMEU.EQ.0.) GO TO 5
  SLPARY(DTIMEU,A50)
5 CONTINUE
  DD 700 I=J,M,N
  IF(I-2) 10,11,12
10  SLPARY(T618,A51)
    DIDEGI(T618,A1,RTEST)
    MLTPLY(K821,RTEST,K864,TTEST)
    DELAY1(A50,A51,TTEST,K890,TTEST)
    SLPARY(K890,A54)
    ARYSTO(K912,VTEST,A57+1)
  GO TO 13
11  SLPARY(T636,A52)
    DIDEGI(T636,A1,RTEST)
    MLTPLY(K822,RTEST,K864,TTEST)
    DELAY1(A50,A52,TTEST,K891,TTEST)
    SLPARY(K891,A55)
    ARYSTO(K912,VTEST,A58+1)
  GO TO 13
12  SLPARY(T654,A53)
    DIDEGI(T654,A1,RTEST)
    MLTPLY(K823,RTEST,K864,TTEST)

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      DELAY1(A50,A53,TTEST,K892,ITEST)
      SLPARY(K892,A56)
      ARYSTO(K912,VTEST,A59+1)
13  CONTINUE
      REM DETERMINE BYPASSED FRACTION
      RTEST=XK(I+331)
      STTEST=XK(I+365)
      VTEST = XK(I+456)
      IF(K(I+368)) 20,30,30
20  IF(RTEST.LE.STTEST) GO TO 35
25  DIDEGL(RTEST,A10,UTEST)
      IF(UTEST.LE.VTEST) GO TO 39
      K(I+368)= 1
      DIDEGL(RTEST,A10,UTEST)
      VTEST=UTEST
      GO TO 39
30  IF(RTEST.GE.STTEST) GO TO 25
35  DIDEGL(RTEST,A11,UTEST)
      IF(UTEST.GE.VTEST) GO TO 39
      K(I+368)= -1
      DIDEGL(RTEST,A11,UTEST)
      VTEST=UTEST
39  CONTINUE
      XK(I+456) = VTEST
      IF(I-2) 40,41,42
40  SLPARY(VTEST,A57)
      CNVLTN(A50,A57,0,2,K879)
      GO TO 43
41  SLPARY(VTEST,A58)
      CNVLTN(A50,A58,0,2,K880)
      GO TO 43
42  SLPARY(VTEST,A59)
      CNVLTN(A50,A59,0,2,K881)
43  CONTINUE
      REM DETERMINE COLD SIDE REGENERATOR FLOW
      FLORGC = (1.-XK(I+374))*XK(I+5)
      REM DETERMINE REGENERATOR COLD SIDE DELAY
      REM IF RP FRACTION IS LARGE, SET FLORGC TO A SMALL FINITE VALUE
      IF(XK(I+374).GT.XK(381)) FLORGC=(1.-XK(381))*XK(I+5)
      TTEST=(XK(I+385) + XK(I+377))/2.
      DIDEGL(TTEST,A1,RTEST)
      TTEST=XK(385)*(1./FLORGC)*RTEST*XK(361)
      REM SLIDE DELAY INTO ARRAY AND DETERMINE DELAY, COND. OUTLET TO
      REM REGEN HOT INLET
      IF(I-2) 70,80,90
70  SLPARY(TTEST,A78)
      DIDEGL(K893,A1,RTEST)
      MLTPLY(K821,RTEST,K867,TTEST)
      TTEST=TTEST-DTIMEI
      REM DELAY1(A50,A60,TTEST,K896,ITEST) DELETED DUE TO INSTABILITY
      CNVLTN(A50,A60,0,2,K896)
      XK(392) = XK(392) + 460.
      XK(464) = XK(460) + (XK(392) - XK(460))*(.53 + .002*XK(6) + .018*
1  XK(462))
      DH = (XK(460) - XK(464))*(.152 + .0000225*(XK(464) + XK(460)))
1  *XK(462)/XK(6)
      X = 116440.5 + 2401.364*DH + XK(392)*(682.4676 + XK(392))
      TOW = SQRT(X) - 341.2338
      XK(467) = XK(461) + .75*(TOW - XK(461))
      DH = (XK(461) - XK(467))*3.47*XK(463)/XK(6)
      X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)
      XK(392) = SQRT(X) - 341.2338 - 460.
      XK(464) = XK(464) - 460.
      XK(467) = XK(467) - 460.

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      SLPARY(K896,A63)
GO TO 100
80      SLPARY(TTEST,A79)
      D1DEG1(K894,A1,RTEST)
      MLTPLY(K822,RTEST,K867,TTEST)
      TTEST=TTEST-DTIMEU
      REM DFLAY1(A50,A61,TTEST,K897,I TEST) DELETED DUE TO INSTABILITY
      CNVLTN(A50,A61,0,2,K897)
      XK(393) = XK(393) + 460.
      XK(465) = XK(460) + (XK(393) - XK(460))*(.53 + .002*XK(7) + .018*
1      XK(462))
      DH = (XK(460) - XK(465))*(.152 + .0000225*(XK(465) + XK(460)))
1      *XK(462)/XK(7)
      X = 116440.5 + 2401.364*DH + XK(393)*(682.4676 + XK(393))
      TOW = SQRT(X) - 341.2338
      XK(468) = XK(461) + .75*(TOW - XK(461))
      DH = (XK(461) - XK(468))*3.47*XK(463)/XK(7)
      X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)
      XK(393) = SQRT(X) - 341.2338 - 460.
      XK(465) = XK(465) - 460.
      XK(468) = XK(468) - 460.
      SLPARY(K897,A64)
GO TO 100
90      SLPARY(TTEST,A80)
      D1DEG1(K895,A1,RTEST)
      MLTPLY(K823,RTEST,K867,TTEST)
      TTEST=TTEST-DTIMEU
      REM DELAY1(A50,A62,TTEST,K898,I TEST) DELETED DUE TO INSTABILITY
      CNVLTN(A50,A62,0,2,K898)
      XK(394) = XK(394) + 460.
      XK(466) = XK(460) + (XK(394) - XK(460))*(.53 + .002*XK(8) + .018*
1      XK(462))
      DH = (XK(460) - XK(466))*(.152 + .0000225*(XK(466) + XK(460)))
1      *XK(462)/XK(8)
      X = 116440.5 + 2401.364*DH + XK(394)*(682.4676 + XK(394))
      TOW = SQRT(X) - 341.2338
      XK(469) = XK(461) + .75*(TOW - XK(461))
      DH = (XK(461) - XK(469))*3.47*XK(463)/XK(8)
      X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)
      XK(394) = SQRT(X) - 341.2338 - 460.
      XK(466) = XK(466) - 460.
      XK(469) = XK(469) - 460.
      SLPARY(K898,A65)
100 CONTINUE
      REM COMPUTE REGEN HOT SIDE DELAY
      TTEST=(XK(I+394) + XK(I+391))/2.
      D1DEG1(TTEST,A1,RTEST)
      XK(33)=XK(385)*XK(I+316)*RTEST*XK(364)
      REM FIND TERMINAL ENTHALPIES AND UA OF EACH REGENERATOR
      IF(I-2) 110,120,130
110      D3DEG1(K890,K896,K6,A38,RTEST)      $UA
      D1DEG1(K896,A24,STEST)                  $HH1
      D1DEG1(K899,A24,TTEST)                  $HH2
      D1DEG1(K890,A24,UTEST)                  $HC1
      D1DEG1(K882,A24,VTEST)                  $HC2
      GO TO 140
120      D3DEG1(K891,K897,K7,A38,RTEST)      $UA
      D1DEG1(K897,A24,STEST)                  $HH1
      D1DEG1(K900,A24,TTEST)                  $HH2
      D1DEG1(K891,A24,UTEST)                  $HC1
      D1DEG1(K883,A24,VTEST)                  $HC2
      GO TO 140
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130      D3DFG1(K892,K898,K8,A38,RTEST)      $IJA
          D1DFG1(K898,A24,STEST)              $HH1
          D1DEG1(K901,A24,TTEST)              $HH2
          D1DEG1(K892,A24,UTEST)              $HC1
          D1DEG1(K884,A24,VTEST)              $HC2

140 CONTINUE
      REM COMPUTE TEMPERATURE AND ENTHALPY DROPS ON EACH SIDE
      UA=RTEST
      HH1=STEST
      HH2=TTEST
      HC1=UTEST
      HC2=VTEST
      DHH=ABS(HH1-HH2)
      DHC=ABS(HC1-HC2)
      DTH=ABS(XK(I+391)-XK(I+394))
      DTC=ABS(XK(I+385)-XK(I+377))
      CC=FLORGC*(1./DTC)*DHC
      CH=XK(I+5)*(1./DTH)*DHH
      BETA=CC/CH
      RNTU=UA/CC
      ET=EXP(-RNTU*(1.-BETA))
      EFF=(1.-ET)/(1.-BETA*ET)
      REM COMPUTE REGEN GAINS BASED ON REGEN INLET CONDITIONS
      RTEST=1.-EFF
      STEST=EFF
      TTEST=EFF*BETA
      UTEST=1.-TTEST
      REM SLIDE GAIN CONSTANTS INTO ARRAYS AND
      REM DETERMINE TRANSIENT OUTLET TEMPS
      IF(I-2) 150,160,170

150      SLPARY(RTEST,A66)  $SYSTEM 1
          SLPARY(STEST,A67)
          SLPARY(TTEST,A68)
          SLPARY(UTEST,A69)
          DELAY2(A50,A54,A78,VTEST,JTEST)
          CNVLTE(A50,A54,A66,JTEST,1,RTEST)  $OUTPUT T11
          CNVLTE(A50,A63,A67,0,1,STEST)      $OUTPUT T12
          DELAY1(A50,A63,K33,VTEST,JTEST)
          CNVLTE(A50,A54,A68,0,1,TTEST)      $OUTPUT T21
          CNVLTE(A50,A63,A69,JTEST,1,UTEST)   $OUTPUT T22
      VTFST=TTEST+UTEST
      SLPARY(VTEST,A81)
      GO TO 180

160      SLPARY(RTEST,A70)
          SLPARY(STEST,A71)
          SLPARY(TTEST,A72)
          SLPARY(UTEST,A73)
          DELAY2(A50,A55,A79,VTEST,JTEST)
          CNVLTE(A50,A55,A70,JTEST,1,RTEST)  $OUTPUT T11
          CNVLTE(A50,A64,A71,0,1,STEST)      $OUTPUT T12
          DELAY1(A50,A64,K33,VTEST,JTEST)
          CNVLTE(A50,A55,A72,0,1,TTEST)      $OUTPUT T21
          CNVLTE(A50,A64,A73,JTEST,1,UTEST)   $OUTPUT T22
      VTEST=TTEST + UTEST
      SLPARY(VTEST,A82)
      GO TO 180

170      SLPARY(RTEST,A74)  $SYSTEM 3
          SLPARY(STEST,A75)
          SLPARY(TTEST,A76)
          SLPARY(UTEST,A77)
          DELAY2(A50,A56,A80,VTEST,JTEST)
          CNVLTE(A50,A56,A74,JTEST,1,RTEST)  $OUTPUT T11
          CNVLTE(A50,A65,A75,0,1,STEST)      $OUTPUT T12
          DELAY1(A50,A65,K33,VTEST,JTEST)

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      CNVLTE(A50,A56,A76,0,1,TTEST)      $OUTPUT T21
      CNVLTE(A50,A65,A77,JTEST,1,UTEST)   $OUTPUT T22
VTEST=TTEST + UTEST                      F
      SLPARY(VTEST,A83)
      REM COLD + HOT TRANSIENT OUTLET TEMPS
180 XK(I+377)=RTEST + STFST                F
      XK(I+394)=TTEST + UTEST              F
      TTEST = (XK(I + 391) + XK(I + 394))/2.    F
      DIDEGL(TTEST,A3,UTEST)                $ SEC REG HOT CP
      TTEST = (XK(I + 377) + XK(I + 385))/2.    F
      DIDEGL(TTEST,A3,VTEST)                $ SEC REG COLO CP
      XK(I + 377) = XK(I + 385) + ((XK(I + 391) - XK(I + 394))*UTEST)/
1  ((1. - XK(I + 374))*VTEST)              F
      IF (XK(I + 377).GT.XK(I + 391)) XK(I + 377) = XK(I + 391)    F
      XK(I + 377) = (XK(I + 377) + XK(I + 322))/2.    F
      XK(I + 322) = XK(I + 377)            F
      REM COMPUTE DELAY TO RAD INLET AND SET RAD INLET TEMP
      IF(I-2) 190,200,210                  F
190      DIDEGL(K899,A1,RTEST)
      MLTPLY(K821,RTEST,K869,TTEST)
      DELAY1(A50,A81,TTEST,T601,ITEST)
      GO TO 220                              F
200      DIDEGL(K900,A1,RTEST)
      MLTPLY(K822,RTEST,K869,TTEST)
      DELAY1(A50,A82,TTEST,T619,ITEST)
      GO TO 220                              F
210      DIDEGL(K901,A1,RTEST)
      MLTPLY(K823,RTEST,K869,TTEST)
      DELAY1(A50,A83,TTEST,T637,ITEST)
220 CONTINUE                              F
      REM COMPUTE CONDENSER INLET TEMP
      IF(XK(I+374).GT.XK(381)) GO TO 290      F
      RTEST=XK(I+385)                        F
      STEST=XK(I+377)                        F
      DIDEGL(RTEST,A24,TTEST)                $ENTHALPY BYPASS
      DIDEGL(STEST,A24,UTEST)                $REGEN ENTHALPY
260 VTEST=TTEST*XK(I+374) + UTEST*(1.-XK(I+374))    F
      DIDEGL(VTEST,A49,RTEST)                $TEMP OUT OF VALVE
      XK(I+403)=RTEST                        F
      GO TO 300                              F
290 XK(I+403)=XK(I+385)                      F
300 CONTINUE                              F
      IF (INDEX1) 450, 450, 301              F
301 INDEX2 = 1                              F
      DTEMP=XK(447)                          F
      ISGN=K(448)                            F
      XK(I + 365) = XK(I + 331)              F
310 T2OLD=XK(I+331)                          F
      T4OLD=XK(I+388)                        F
      IF(I-2) 320,330,340                    F
320      DIDEGL(K908,A24,RTEST)
      DIDEGL(K893,A24,STEST)
      GO TO 350                              F
330      DIDEGL(K909,A24,RTEST)
      DIDEGL(K894,A24,STEST)
      GO TO 350                              F
340      DIDEGL(K910,A24,RTEST)
      DIDEGL(K895,A24,STEST)
350 CONTINUE                              F
      IF (INDEX2 - 100) 354, 354, 445        F
354 QGLY = XK(I + 5)*(STEST - RTEST)          F
      DTGAS=XK(I+371)-XK(I+331)              F
351 QGAS = DTGAS*(3.44*WTH230(I)/DTIMEU + XK(I + 336)/XK(I + 415)*1.0)F
1      +(DMASS(I)*1160.+DMASS(I)*DTGAS*1.0)/DTIMEU    F

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352 XK(I + 331) = XK(I + 388) - XK(I + 316)*(49.2287949 + F
1      0.687469198*QGAS + 9.0145E-7*QGAS**2) F
      IF(ABS(QGLY-QGAS).LT.XK(407)) GO TO 450 F
      ISGNSV=ISGN F
      IF(QGLY.LT.QGAS) ISGN=+1 F
      IF(QGLY.GT.QGAS) ISGN=-1 F
      TINCR=DTEMP*ISGN F
      IF(ISGN.EQ.ISGNSV) GO TO 440 F
      XK(I+331)=T2OLD F
      XK(I+388)=T4OLD F
      DTEMP=DTEMP/2.0 F
      INDEX2 = INDEX2 + 1 F
      GO TO 310 F
440 XK(I+388)=XK(I+388)+TINCR F
      INDEX2 = INDEX2 + 1 F
      GO TO 310 F
445 WRITE (6, 446) F
446 FORMAT (1H0, 74HCONDENSER HEAT BALANCE NOT COMPLETED WITHIN SPECIF F
      ITED NUMBER OF ITERATIONS) F
450 QCOND(I)=QGAS F
      IF(I-2) 451,452,453 F
451      SLPARY(K893,A60) F
      GO TO 700 F
452      SLPARY(K894,A61) F
      GO TO 700 F
453      SLPARY(K895,A62) F
      REM END OF LOOP***** F
700 CONTINUE F
      INDEX1 = 1 F
      REM***** F
      END F
      BCD 3OUTPUT CALLS F
      COMMON/BRAVO/QCOND(3),DMASS(3),WTH230(3) F
      COMMON/CHARLE/ J, M, N F
      COMMON/ECHO/ IPOINT F
      COMMON/FOXTRT/ PCKOH(3) F
      DIMENSION ATEMP(50) F
      DIMENSION XK(1) F
      DIMENSION CRTAR1(200), CRTAR2(200), CRTAR3(200), CRTAR4(200), F
1 CRTAR5(72), CRTAR6(72), CRTAR7(63) F
      DIMENSION DATE(2) F
      DATA ITIT/0/ F
      DATA CRTAR5/ 'MISS', 'ION ', 'TIME', ' - ', ' MIN', 13* ' ' / F
      DATA CRTAR6/ 'SYST', 'EM T', 'EMPE', 'RATU', 'RES ', ' . ', ' DEG ', F
1 'F ', 10* ' ' / F
      EQUIVALENCE (XK(1),K(1)) F
      CALL CAMRAV(9) F
      TIME = 0.0 F
      DO 100 N1 = 1, 63 F
      CRTAR7(N1) = TIME F
      TIME = TIME + 3.0 F
100 CONTINUE F
      REM SOLVE FOR RADIATOR PRESSURE DROP F
      MLTPLY(K6,K6,K585,K682) $RADIATOR PRESSURE DROP FOR SYSTEM 1 F
      MLTPLY(K7,K7,K589,K683) $RADIATOR PRESSURE DROP FOR SYSTEM 2 F
      MLTPLY(K8,K8,K593,K684) $RADIATOR PRESSURE DROP FOR SYSTEM 3 F
      D1DEG1(K682,A84,K6) $ FLOW RATE - SYSTEM 1 F
      D1DEG1(K683,A84,K7) $ FLOW RATE - SYSTEM 2 F
      D1DEG1(K684,A84,K8) $ FLOW RATE - SYSTEM 3 F
      REM FLUID HEAT LOSS FOR SYSTEM 1 F
      QMTRI(16,A9+1,G601,A25+1) F
      REM FLUID HEAT LOSS FOR SYSTEM 2 F
      QMTRI(16,A9+19,G619,A25+17) F

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      REM FLUID HEAT LOSS FOR SYSTEM 3
      QMTRI(16,A9+37,G637,A25+33)
      IF(K(9).EQ.1) GO TO 1
      SUMARY(16,A25+1,K801)
      GO TO 2
1 CONTINUE
      SUMARY(10,A25+1,K801)
2 IF(K(10).EQ.1) GO TO 3
      SUMARY(16,A25+17,K802)
      GO TO 4
3 CONTINUE
      SUMARY(10,A25+17,K802)
4 IF(K(11).EQ.1) GO TO 5
      SUMARY(16,A25+33,K803)
      GO TO 6
5 CONTINUE
      SUMARY(10,A25+33,K803)
6 CONTINUE
      CALL DATOUT
      WRITE(6,11)
11 FORMAT(5X,99HSYSTEM    POWER    CURRENT    VOLTAGE    TSI        TSE
1 TCIP      TCEP      QCOND      W-COND      WS-RATE, 3X,
2 12HTO2      TH2)
      WRITE(6,12)
12 FORMAT(14X,99HWATTS    AMPS      VOLTS      DEGF      DEGF      DEGF
1 DEGF      BTU/HR      LB/HR      PERCENT, 3X, 12HDEGF      DEGF, /)
      DO 13 I=J,M,N
13 WRITE(6,14) I,XK(I+412),XK(I+349),XK(I+353),XK(I+339),XK(I+342),
1      XK(I+371),XK(I+331),QCOND(I),XK(I+450),XK(I+453),
2 XK(I+463),XK(I+466),PCKOH(I)
14 FORMAT(6X,12,4X,2F8.2,1X,5F7.2,F10.2,F10.3,2F9.2,F8.2,F9.3)
      WRITE(6,15)
15 FORMAT (//)
      WRITE(6,16)
16 FORMAT(5X,114HSYSTEM    FLOW RATE    QRAD      TRADIN    TRADOUT    DPRAF
1D      TSRGI      TSRCE      TSRHI      TSRHE      TCIS      TCES      BPFSI
      WRITE(6,17)
17 FORMAT(16X,95HLB/HR      BTU/HR      DEGF      DEGF      PSIA      DEGF
1 DEGF      DEGF      DEGF      DEGF      DEGF, /)
      DO 18 I=J,M,N
18 WRITE(6,19) I,XK(I+5),XK(I+296),T(I+243),T(I+240),XK(I+212),
1      XK(I+385),XK(I+377),XK(I+391),XK(I+394),XK(I+403),
2      XK(I+389),XK(I+374)
19 FORMAT(6X,12,5X,F8.2,1X,2F9.2,F10.2,F8.3,6F9.2,F8.4)
      WRITE(6,20)
20 FORMAT(//7X,120HPANEL 1      PANEL 2      PANEL 3      PAF
1NEL 4      PANEL 5      PANEL 6      PANEL 7      PANEF
2L 8, /, 5X, 123HIN      OUT      IN      OUT      IN      OUT      IF
3N      OUT      IN      OUT      IN      OUT      IN      F
4      OUT, /)
      DO 21 I1 = 193,208
      J1 = 209 - I1
21 ATEMP(J1) = T(I1)
      DO 22 I2 = 209,224
      J2 = 241 - I2
22 ATEMP(J2) = T(I2)
      DO 23 I3 = 225,240
      J3 = 273 - I3
23 ATEMP(J3) = T(I3)
      WRITE(6,25) (ATEMP(KT),KT = 1,16)
      WRITE(6,25) (ATEMP(KT),KT = 17,32)
      WRITE(6,25) (ATEMP(KT),KT = 33,48)
25 FORMAT(1X,16F8.1)
      NP = 125

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CRTAR1(IPDINT) = XK(343) F
CRTAR2(IPDINT) = XK(332) F
CRTAR3(IPDINT) = T(244) F
CRTAR4(IPDINT) = T(241) F
IF (IPDINT.EQ.NP) GO TO 30 F
IPDINT = IPDINT + 1 F
GO TO 50 F
30 CONTINUE F
IF (ITIT.EQ.0) CALL CDATEV(DATE) F
IF (ITIT.GT.0) GO TO 50 F
CALL GRF3TV(-1,38,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR1(1),200.,0., F
1 500.,0.) F
CALL RITE2V(331,1010,1023,90,2,20,1,'SYSTEM 1 - 30 AMPS',IRLY) F
CALL PRINTV(8,DATE,943,995) F
CALL GRF3TV( 0,63,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR2(1),200.,0., F
1 500.,0.) F
CALL GRF3TV( 0,55,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR3(1),200.,0., F
1 500.,0.) F
CALL GRF3TV( 0,44,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR4(1),200.,0., F
1 500.,0.) F
CALL GRF3TV(-1,38,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR1(63),200.,0., F
1 500.,0.) F
CALL RITE2V(331,1010,1023,90,2,20,1,'SYSTEM 1 - 25 AMPS',IRLY) F
CALL PRINTV(8,DATE,943,995) F
CALL GRF3TV( 0,63,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR2(63),200.,0., F
1 500.,0.) F
CALL GRF3TV( 0,55,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR3(63),200.,0., F
1 500.,0.) F
CALL GRF3TV( 0,44,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR4(63),200.,0., F
1 500.,0.) F
ITIT = 2 F
50 CONTINUE F
END F
```



USER SUBROUTINE LISTINGS

```
0001      SUBROUTINE CNVLTN(DT,V1,NST,NFCN,V2)
0002      DOUBLE PRECISION DTDP,DTNS,V1J,V1JP1,VAV,TMT,TMT0,V2DP,XSFER,
0003      1      SCALE,RISB,RMXSB
0004      DIMENSION DT(1),V1(1)
0004      EQUIVALENCE(D,N)
0005      C
0006      C      V1 MUST BE DIMENSIONED NOT LONGER THAN
0007      C      (DIMENSION OF DT)+1
0008      C
0009      D = DT(1)
0010      IDT = N
0011      D = V1(1)
0012      IV1 = N
0013      NT = IDT+1-IV1
0014      IF(NT) 169,5,5
0015      5 IF(NST) 15,15,25
0016      15 NST = IDT+1
0017      25 V2DP = 0.0000
0018      TMT = 0.0000
0019      C
0020      C *****
0021      MXS8 = 10
0022      C *****
0023      RMXSB = MXS8
0024      NSTM1 = NST-1
0025      DO 80 I=1,NSTM1
0026      J = NST-I+1
0027      DTDP = DT(J)
0028      JS = J-NT
0029      V1J = V1(JS)
0030      V1JP1 = V1(JS+1)
0031      DTNS = DTDP/RMXSB
0032      TMT0 = TMT
0033      DO 70 ISB=1,MXS8
0034      IF(ISB-1) 30,30,40
0035      30 TMT = TMT+0.5000*DTNS
0036      GO TO 45
0037      40 TMT = TMT+DTNS
0038      45 RISB = ISB
0039      SCALE = RISB/RMXSB
0040      VAV = V1JP1+(V1JP1-V1J)*SCALE
0041      70 V2DP = V2DP+XSFER(NFCN,TMT)*VAV*DTNS
0042      TMT = TMT0+DTDP
0043      80 CONTINUE
0044      V2 = V2DP
0045      RETURN
0046      169 WRITE(6,170)
0047      170 FORMAT(43H ERROR IN DIMENSIONING OF ARRAYS FOR CNVLTN)
0048      RETURN
0049      END
```



```
0001      SUBROUTINE CNVLTE(DT,V1,GAIN,NST,NFCN,V2)
0002      DOUBLE PRECISION DTDP,DTNS,V1J,V1JP1,VAV,GJ,GJP1,GAV,TMT,TMT0,
0003      1      V2DP,XSFER,SCALE,RISA,RMXSB
0004      DIMENSION DT(1),V1(1),GAIN(1)
0004      EQUIVALENCE(D,N)

C
C      V1 AND GAIN MUST BE DIMENSIONED EQUAL LENGTH AND MAY
C      NOT BE LONGER THAN (DIMENSION OF DT)+1
C

0005      D = DT(1)
0006      IDT = N
0007      O = V1(1)
0008      IV1 = N
0009      O = GAIN(1)
0010      IG = N
0011      NT = IDT+1-IV1
0012      IF(NT) 169,5,5
0013      5 NT = IDT+1-IG
0014      IF(NT) 169,10,10
0015      10 IF(IG-IV1) 169,15,169
0016      15 IF(NST) 20,20,25
0017      20 NST = IDT+1
0018      25 V2DP = 0.0000
0019      TMT = 0.0000
C      *****
0020      MXSB = 10
C      *****
0021      RMXSB = MXSB
0022      NSTM1 = NST-1
0023      DO 80 I=1,NSTM1
0024      J = NST-I+1
0025      DTDP = DT(J)
0026      JS = J-NT
0027      V1J = V1(JS)
0028      V1JP1 = V1(JS+1)
0029      GJ = GAIN(JS)
0030      GJP1 = GAIN(JS+1)
0031      DTNS = DTDP/RMXSB
0032      TMT0 = TMT
0033      DO 70 ISB=1,MXSB
0034      IF(ISB-1) 30,30,40
0035      30 TMT = TMT+0.5000*DTNS
0036      GO TO 45
0037      40 TMT = TMT+DTNS
0038      45 RISA = ISB
0039      SCALE = RISA/RMXSB
0040      VAV = V1JP1+(V1JP1-V1J)*SCALE
0041      GAV = GJP1+(GJP1-GJ)*SCALE
0042      70 V2DP = V2DP+XSFER(NFCN,TMT)*VAV*GAV*DTNS
0043      TMT = TMT0+DTDP
0044      80 CONTINUE
0045      V2 = V2DP
0046      RETURN
0047      169 WRITE(6,170)
0048      170 FORMAT(43H ERROR IN DIMENSIONING OF ARRAYS FOR CNVLTE)
0049      RETURN
0050      END
```



```

0001      SUBROUTINE DELAY1(TAP, ARR, TAU, VAL, INDX)
0002      DIMENSION TAR(1), ARR(1)
0003      EQUIVALENCE(D,N)
0004      D = TAR(1)
0005      ITAR = N + 1
0006      O = ARR(1)
0007      IARR = N + 1
0008      JTAR = ITAR
0009      JARR = IARR
0010      DT = TAU - TAR(JTAR)
0011      10  JTAR = JTAR - 1
0012          IF (JTAR - 2) 100, 20, 20
0013      20  JARR = JARR - 1
0014          IF (JARR - 2) 200, 30, 30
0015      30  IF (DT) 60, 60, 40
0016      40  DT = DT - TAR(JTAR)
0017          GO TO 10
0019      60  INDX = JARR
0019          VAL = ARR(JARR)
0020      RETURN

C
C      ERROR MESSAGES
C
0021      100  WRITE (6, 101)
0022      101  FORMAT (50H DELAY1 ERROR--TAU EXCEEDS SUM OF SAVED TIME STEPS)
0023          INDX = 2
0024          VAL = ARR(2)
0025          RETURN
0026      200  WRITE (6, 201)
0027      201  FORMAT (28H DELAY1 ERROR--ARR TOO SMALL)
0028          INDX = 2
0029          VAL = ARR(2)
0030          WRITE (6, 250) DTIMEU
0031      250  FORMAT (12H THE TIME IS , F10.5)
0032          RETURN
0033      END
0001      SUBROUTINE DELAY2(TAR, ARR, TAU, VAL, INDX)
0002      DIMENSION TAR(1), ARR(1), TAU(1)
0003      EQUIVALENCE(D,N)

C
C      TAR MUST BE DIMENSIONED ONE LESS THAN ARR AND TAU
C
0004      D = TAR(1)
0005      ITAR = N
0006      O = ARR(1)
0007      IARR = N
0008      D = TAU(1)
0009      ITAU = N
0010      SUMDT = 0.0
0011      TAUITG = 0.0
0012      J = ITAR + 1 - IARR
0013      IF(J) 69,10,69
0014      10  IF(IARR - ITAU) 69,20,69
0015      20  DO 50 I = 1,ITAR
0016          M = ITAR + 2 - I
0017          SUMDT = SUMDT + TAR(M)
0018          TAUAVI = (TAU(M) + TAU(M + 1))/2.0
0019          TAUITG = TAUITG + TAUAVI*TAR(M)
0020          TAUAVC = (1./SUMDT)*TAUITG
0021          IF (SUMDT - TAUAVC) 50, 60, 60
0022      50  CONTINUE
0023          WRITE (6, 51)

```



```
0024      51  FORMAT (43H MEAN TAU OUT OF RANGE OF TAR SUM IN DELAY2)  
0025      60  VAL = ARR(M)  
0026          INDX = M  
0027          RETURN  
0028      69  WRITE (6, 70)  
0029      70  FORMAT (43H ERROR IN DIMENSIONING OF ARRAYS FOR DELAY2)  
0030          RETURN  
0031          END
```

```

0001      SUBROUTINE SLPARY(ARYN,ARY)
0002      DIMENSION ARY(1)
0003      EQUIVALENCE(D,N)
0004      D=ARY(1)
0005      IC=N
0006      DO 10 I=2,IC
0007      10 ARY(I)=ARY(I+1)
0008      ARY(IC+1)=ARYN
0009      RETURN
0010      END

```

```

0001      SUBROUTINE ARYSTO(N,X,A)
0002      DIMENSION A(1)
0003      X = A(N)
0004      RETURN
0005      END

```

```

0001      DOUBLE PRECISION FUNCTION XSFER(NFCN,T)
0002      DOUBLE PRECISION T
0003      XSFER = 0.0000
0004      C *****
0005      C NFCN=1 IS SECONDARY REGENERATOR FUNCTION
0006      IF(NFCN.NE.1) GO TO 10
0007      IF(T.GT.0.5277000) RETURN
0008      XSFER = (1.000/0.52770-02)*DEXP(-T/0.52770-02)
0009      RETURN
0010      C *****
0011      C 10 CONTINUE
0012      C *****
0013      C NFCN=2 IS SECONDARY BYPASS VALVE FUNCTION
0014      IF(NFCN.NE.2) GO TO 20
0015      IF(T.GT.0.2833000) RETURN
0016      XSFER = (1.000/0.28330-02)*DEXP(-T/0.28330-02)
0017      RETURN
0018      C *****
0019      C 20 CONTINUE
0020      RETURN
0021      END

```

```

0001      SUBROUTINE DATOUT
0002      COMMON/FIXCON/ N
0003      DIMENSION N(1)
0004      IF (N(28).GE.58.OR.N(29).EQ.0) CALL HEADNG
0005      N(29) = N(28) + 4
0006      WRITE (6, 100) N(1), N(2), N(35), N(17), N(36), N(15), N(37),
0007      1 N(30)
0008      100 FORMAT (/1X, 10H* * * */1X, 4HTIME, 1PE13.5, 1X, 6HDTIMEU,
0009      1 1PE13.5, 1X, 7HCSGMINI, 15, 1H), 1X, 1PE13.5, 1X, 7HDTMPCCT, 15,
0010      2 1H), 1X, 1PE13.5, 1X, 7HARLXCCI, 15, 1H), 1X, 1PE13.5 //)
0011      RETURN
0012      END

```

```

0001      SUBROUTINE HEADNG
0002      COMMON/FIXCON/ N
0003      COMMON/TITLE/ H
0004      DIMENSION N(1), H(20)
0005      N(28) = 15
0006      N(29) = N(29) + 1
0007      WRITE (6, 100) N(29), H
0008      100 FORMAT (1H1, 116X, 4HPAGE, 2X, 17 / 4X, 121HSYSTEMS IMPROVED NUMER
0009      1ICAL DIFFERENCING ANALYZER * SINDA * NORTH AMERICAN ROCKWE
0010      2LL CORPORATION - SPACE DIVISION, //, 5X, 20A6//)
0011      RETURN
0012      END

```




```

0001      SUBROUTINE GRF3TV(L,ISYM,BCDX,BCDY,NP,X,Y,XMAX,XMIN,YMAX,YMIN)  GRF00010
C
C      GRAF3V PLOTS 1,2, OR 3 GRIDS PER PAGE ON THE SC 4020  GRF00020
C
C      *** NOTATION ***  GRF00030
C
C      L      NO. OF GRAPHS PER FRAME(1,2,OR3).  GRF00040
C      IF L IS NEGATIVE - FRAME WILL BE ADVANCED AND NP POINTS  GRF00050
C      WILL BE PLOTTED ON GRID NO.1  GRF00060
C      IF L IS POSITIVE - NP POINTS WILL BE PLOTTED ON GRID 2 OR 3 GRF00070
C      IF L IS ZERO - NP POINTS WILL BE PLOTTED ON PREVIOUS GRID  GRF00080
C
C      ISYM   PLOTTING SYMBOL  GRF00090
C
C      BCDX   ALPHA-NUMERIC CHARACTERS FOR THE X AXIS & Y AXIS. THESE  GRF00100
C      BCDY   ARRAYS ARE LIMITED TO 72 CHARACTERS EACH AND THE LAST  GRF00110
C
C      NP     NUMBER OF POINTS TO BE PLOTTED  GRF00120
C      IF NP IS NEGATIVE - THE POINTS WILL BE CONNECTED, THUS THE  GRF00130
C      VALUES OF X MUST BE IN ASCENDING ORDER  GRF00140
C
C      XMAX   MAXIMUM & MINIMUM VALUES OF X & Y. IF BOTH MINIMUM AND  GRF00150
C      XMIN   MAXIMUM VALUES OF X ARE ZERO, THE ARRAY IS SEARCHED FOR  GRF00160
C      YMAX   THE APPROPRIATE VALUES. THE SAME PROCEDURE IS FOLLOWED  GRF00170
C      YMIN   FOR MINIMUM & MAXIMUM Y  GRF00180
C
C      DIMENSION X(500),Y(500),BCDX(18),BCDY(18)  GRF00190
C      NZ = IABS(NP)  GRF00200
C      IF(NZ .EQ. 0) GO TO 60  GRF00210
C      IF(L .EQ. 0) GO TO 30  GRF00220
C      XL = XMIN  GRF00230
C      XR = XMAX  GRF00240
C      IF((XL .NE. 0.0) .OR. (XR .NE. 0.0)) GO TO 15  GRF00250
C      XL = X(1)  GRF00260
C      XR = X(1)  GRF00270
C      DO 10 K = 1,NZ  GRF00280
C      XL = AMIN1(X(K),XL)  GRF00290
C      10 XR = AMAX1(X(K),XR)  GRF00300
C      15 YB = YMIN  GRF00310
C      YT = YMAX  GRF00320
C      IF((YT .NE. 0.0) .OR. (YB .NE. 0.0)) GO TO 25  GRF00330
C      YB = Y(1)  GRF00340
C      YT = Y(1)  GRF00350
C      DO 20 J = 1,NZ  GRF00360
C      YB = AMIN1(Y(J),YB)  GRF00370
C      20 YT = AMAX1(Y(J),YT)  GRF00380
C      25 IF(L .LT. 0) L1 = 1  GRF00390
C      IF(L .GT. 0) L1 = 2  GRF00400
C      NCX = NBLANC(BCDX,18)  GRF00410
C      NCY = NBLANC(BCDY,18)  GRF00420
C      LGD = IABS(L1)  GRF00430
C      DCX = 10.0  GRF00440
C      DCY = 10.0  GRF00450
C      INCRY = -14  GRF00460
C      CALL MARGNP (L,ICV)  GRF00470
C      IX = 524 - 4*NCX  GRF00480
C      IY = ICY + 7*NCY  GRF00490
C      IF(LGD .EQ. 1) IY1 = 0  GRF00500
C      IF(LGD .EQ. 2) IY1 = ICY - 253  GRF00510
C      IF(LGD .EQ. 3) IY1 = ICY - 169  GRF00520
C      CALL OXDYV(1,XL,XR,DX,N,1,NX,DCX,IER)  GRF00530
C      CALL OXDYV(2,YB,YT,DY,M,J,NY,DCY,IER)  GRF00540
C      CALL GRIDIV(L1,XL,XR,YB,YT,DX,DY,N,M,1,J,NX,NY)  GRF00550
C      CALL PRINTV(NCX,BCDX,IX,IY1)  GRF00560
C      CALL APRNTVIO,INCRY,NCY,BCDY,0,IY)  GRF00570
C      30 CALL APLDTV(NZ,X,Y,1,1,1,ISYM,IER)  GRF00580
C      IF (NP .GT. 0) GO TO 60  GRF00590
C      DO 50 KK = 1,NZ  GRF00600
C      NXA = NXV(X(KK))  GRF00610
C      NYA = NYV(Y(KK))  GRF00620
C      IF(KK .LT. 2) GO TO 40  GRF00630
C      CALL LINEV(NXO,NYO,NXA,NYA)  GRF00640
C      40 NXO = NXA  GRF00650
C      NYO = NYA  GRF00660
C      50 CONTINUE  GRF00670
C      60 RETURN  GRF00680
C      END  GRF00690

```



```
0001      SUBROUTINE MARGNR(L1,ML3)                                MARG0010
      C                                                                MARG0020
      C 'MARGNR' SETS THE MARGINS FOR PLOTTING 1,2, OR 3 GRIDS PER FRAME MARG0030
      C                                                                MARG0040
0002      DIMENSION L(6,3),IN(3)                                MARG0050
0003      DATA L /24,357,690,24,524,24,690,357,24,524,24,24,178,511,844,262, MARG0060
      L 762,512/, IN /5,3,0/                                MARG0070
0004      IF( L1 .GE. 0 ) GO TO 10                                MARG0080
0005      K = -L1                                                MARG0090
0006      N = 1                                                  MARG0100
0007      10 IC = N + IN(K)                                       MARG0110
0008      ML3 = L(IC,3)                                           MARG0120
0009      CALL SETMIV(24,0,L(IC,1),L(IC,2))                      MARG0130
0010      N = N + 1                                              MARG0140
0011      RETURN                                                  MARG0150
0012      END                                                    MARG0160
```

```
0001      FUNCTION NBLANC(WORD,N)                                NBLK0010
      C                                                                NBLK0020
      C 'NBLANC' DETERMINES NO. OF CHARACTERS IN A HOLLERITH LABEL NBLK0030
      C IF THERE ARE NO CHARACTERS, NBLANC = 0 NBLK0040
      C                                                                NBLK0060
0002      DIMENSION WORD(18)                                NBLK0070
0003      DATA BLANK /' '/                                NBLK0080
0004      DO 10 M = 1,N NBLK0090
0005      I = N - M NBLK0100
0006      IF((WORD(I)-BLANK) .NE. 0.0) GO TO 20 NBLK0110
0007      10 CONTINUE NBLK0120
0008      I = 0 NBLK0130
0009      20 NBLANC = 4*I NBLK0140
0010      RETURN NBLK0150
0011      END NBLK0160
```